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Title: Advances in understanding the evolution of institutions in complex social-ecological systems

Abstract:

Elinor Ostrom and colleagues developed the social-ecological system framework with the aim of synthesizing knowledge to foster a better understanding of the relationship between people, institutions and the environment. Although the framework has facilitated the diagnosis of complex systems; it has thus far struggled to account for the role of history in structuring the range of opportunities and constraints that actors face as they interact with the environment and each other. More recent innovations in measuring institutions and the integration of process-oriented approaches are beginning to provide the tools required to systematically trace the co-evolution of institutions and social-ecological systems. We review the history and development of social-ecological system scholarship, including longstanding concerns regarding the weak inclusion of temporal dynamics. We highlight the contributions of three novel advances – namely the combined IAD-SES framework, the institutional grammar tool, and the power in polycentric governance approach.

Highlights

- Social-ecological systems scholarship has struggled to provide a systematic approach for studying institutional development and change
- This paper presents three advances in understanding institutional change
- The combined IAD-SES framework links variable-oriented and process-oriented research
- The institutional grammar tool provides a systematic approach for classifying institutions
- The power in polycentric governance approach facilitates an understanding of the evolution of power relations

1. Introduction

Institutional analysis and the related social-ecological system (SES) framework has rapidly gained traction as a leading approach for characterizing the structure of complex SESs and analyzing the impacts of a wide range of social, ecological and institutional factors [1-4]. Institutions are broadly defined as the rules, norms and customs of groups that structure human interactions with the environment and each other and include both formal laws and regulations as well as the informal rules and practices of communities [5]. Institutional analysis has made a number of important contributions to the theory and practice of sustainable environmental governance, highlighting the importance of institutional arrangements that support local participation [6-9], are adjusted to local social and ecological conditions [6, 7, 10], and provide mechanisms to ensure that monitors are accountable to resource users [6, 7, 11]. Nonetheless, institutional analysis has also faced longstanding critiques concerning its lack of attention to the factors and processes by which institutions for sustainable environmental governance are developed and change [12]. As a result, although scholars and policymakers might possess knowledge concerning the institutional ingredients of sustainable environmental governance, they often lack an understanding of the longitudinal process by which those institutions are developed and maintained, and the contextual conditions that might facilitate or limit prospects

for change. This paper therefore reviews recent innovations in institutional scholarship on social-ecological systems that may facilitate efforts to address this gap.

1.1. Gaps in understanding longitudinal institutional development and change

The publication of Ostrom's *Governing the Commons* in 1990 represented an important turning point in the theory and practice of environmental governance following decades of research which viewed communities of resource users as uniformly selfish and lacking in terms of both knowledge and capacity to address environmental problems [13, 14]. In reality of course, human societies have a long history of successfully addressing collective action problems and developing a range of formal and informal institutional arrangements to effectively manage resources for extended periods of time [6, 15]. Nonetheless, the tragedy narrative supported the demise of many of these systems as governments, NGOs and private actors asserted control over natural resources [16].

The rediscovery of community-based management led many countries to introduce decentralization reforms to enhance the legal rights of local communities with respect to the use and management of resources [17-19]. These reforms, however, often failed to translate into meaningful change in the structure or performance of environmental governance systems as different path-dependent processes served to undermine the role of communities in resource management. Institutional path-dependence refers to a system of positive feedbacks in which each step along a particular track encourages further steps in the same direction as a result of investments in time, money and resources that increase exit costs [20], and/or political economies that provide some actors with selective incentives and enhanced bargaining power to resist deviations from the current path [21]. Although analysts frequently invoke the concept of path-dependence to explain the persistence of unsustainable institutional arrangements, this concept can also explain the persistence of effective institutions.

Case studies of decentralization processes and outcomes reveal several mechanisms that collectively serve to reinforce existing distributions of power. In some cases, powerful actors (e.g. social and political elites) have used their superior bargaining power, resources and capacity to maintain or even enhance their positions in resource management as decentralization processes unfold [22-25]. In others, government efforts to exert control over resource management have failed to adequately protect resources and also contributed to the erosion of critical skills, knowledge and social capital that underlie sustainable community-based management [26, 27]. As a result, resource-dependent communities often find it difficult to extricate themselves from systems of external control in order to play a meaningful role in the design and implementation of environmental governance. Competing agendas within governments (e.g., conservation versus economic development via large scale resource extraction) can further exacerbate these challenges and contribute to the continued erosion of the rights of local communities [28, 29]. For example, the implementation of the *Forest Rights Act* in India, which protected the historical rights of forest-dependent communities, was systematically undermined by long-standing opposition from wildlife conservation groups, internal resistance from forestry administrators, and accommodation for existing wildlife conservation regulations [25]. Although it is clear that researchers have developed valuable insights about institutional development and change through case studies and meta-analyses, the

lack of a systematic approach has hindered understanding of the underlying conditions and processes that affect institutional change in environmental governance.

There are two core barriers underlying the lack of progress towards a better understanding of institutional change in social-ecological system scholarship. First, institutions are linguistic statements that outline actions that may, may not, or must be taken, by the actors to whom the statement applies, plus any consequences those actors might face for violating them [5]. They include both formal institutions, such as laws and regulations that are written down and easily accessible to the researcher, as well as informal institutions such as rules-in-use and norms that may be widely understood and taken for granted by members of communities but hidden from the casual observer. Collectively these properties (i.e. unstructured text data, unwritten rules) pose an immense challenge for consistently coding and analyzing institutional arrangements to support cross-case comparison and empirical synthesis. Second, social-ecological system scholarship has tended to adopt a variable-oriented approach to identify the social, ecological and institutional correlates of sustainability [30, 31]. The resulting lists of ingredients for sustainable environmental governance, while useful, is often lacking when applied to different problems or different contexts in the absence of corresponding details about the process by which those conditions emerge and influence human interactions with the environment. As a result, there is an urgent need for approaches that facilitate consistent measurement of institutions and the processes by which those institutions are developed and changed to enable the transfer of knowledge across cases. The following section presents three recent innovations that may be used to gain traction on these problems; namely the institutional grammar (IG) tool; the combined institutional analysis and development (IAD) and SES (CIS) framework; and the power in polycentric governance (PPG) approach. The utility of these approaches are further examined by drawing upon a published case study of forest decentralization processes and outcomes in Senegal [22] to show how they might be used to uncover the conditions and processes that facilitate (or undermine) institutional change.

2. Emerging Approaches for the Analysis of Institutional Development and Change

2.1. The CIS Framework

The combined IAD-SES (CIS) framework [32, 33] is an extension of Ostrom's institutional analysis and social-ecological systems frameworks [2, 34, 35] used to diagnose the variables associated with sustainable environmental governance. Although IAD-SES contributions to theory and practice have been immense, analysts have continued to struggle to provide insights concerning the processes by which institutions develop and change. The CIS framework was developed to respond to these issues, providing analysts with an approach to systematically trace the development and effects of institutions across a series of interdependent action situations. Action situations represent spaces in which actors make decisions concerning the use and management of resources [36]. Applications of the CIS framework begin by identifying points of potentially significant social, ecological or institutional change that may mark significant alterations of the social-ecological equilibrium of a case [32]. The analyst then continues to characterize the social, ecological and institutional conditions at the beginning and end of each period bounded by significant institutional or ecological alterations and maps out the network and sequencing of action situations or processes by which further changes in those conditions

might be realized. The approach provides researchers with considerable flexibility in making decisions about which institutional or ecological changes, variables and action situations to include in their analysis, which should instead be guided by theory and research questions.

There are several options for using the CIS framework to analyze institutional development and change in social-ecological systems. First, those interested in understanding how historical factors structure the nature and outcomes of current interactions may examine how the social and economic characteristics of groups affect the incentives, opportunities and constraints they face in one or more action situations. For instance, measures of economic inequality can capture, at least in part, the results of years of social marginalization of certain groups which may undermine their bargaining power in action situations [37] and ability to self-organize to address social dilemmas [38]. Second, historical efforts to restrict the autonomy of local stakeholders might be revealed by analyzing the structure and/or sequencing of the action situation network [39] and its corresponding effects on behaviour and outcomes. For example, the post-decentralization action situations (Figure 1) show how central government actors in Senegal retained control over the use of commercial forest resources in Senegal by sequencing action situations in such a way that local decisions over commercial use of forest resources were subject to external approval of both management plans and logging permissions [22]. As a result, local forest planning and rulemaking processes are limited in practice to making decisions that are consistent with the interests of central government actors, undermining incentives for local stakeholders to invest their time and resources in forest management. In fact in the roughly seven years following decentralization relatively few draft management plans had been developed, and only one of these had been approved by the forest service.

Third, networks of action situations can also be used to endogenize history by tracing the conditions and processes by which those attributes emerged, as shown in the first segment of figure 1. Ribot and Agrawal (2006), for instance, suggest that decentralization reforms in Senegal were introduced to appease international donors who nonetheless neglected to develop mechanisms to supervise their implementation. This allowed central government actors to retain significant control over local forest management through the establishment of the network of action situation described above, and to preserve the flow of benefits they derived from forest resources.

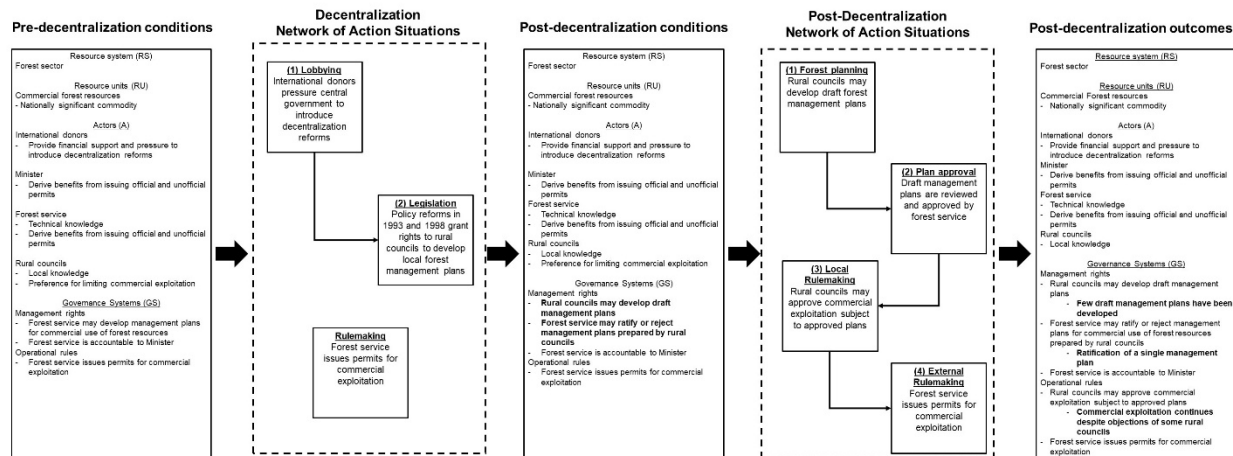


Figure 1: Analysis of decentralization processes and forest governance in Senegal using the CIS framework. The first segment represents the conditions and processes by which forest governance was decentralized in Senegal, while the second segment depicts the conditions and processes by which decisions concerning commercial exploitation of forest resources are made. The sequencing of action situations (if relevant) within a network are indicated by the number of the action situation.

2.2. Building on the CIS Framework using the Institutional Grammar Tool

The CIS framework provides a powerful tool for tracing the dynamic process by which a series of decisions related to the use and management of resources jointly contribute to the social and environmental outcomes experienced by societies. Individual action situations result in decisions that affect the information, incentives, opportunities and constraints that actors face in linked action situations [35]. The CIS framework thus facilitates identification of those action situations which may be most important for understanding institutional change over time, allowing the analyst to focus attention on the rule structures of those action situations.

Individual action situations are structured by seven types of rules: position, boundary, choice, aggregation, payoff, information, and scope rules. These rule types are identified using the institutional grammar tool (IGT) [5, 34]. The IGT is a method for parsing the syntax of individual institutional statements – the individual written or unwritten rules, norms, and strategies used by individuals to structure action situations. This syntax consists of five basic grammatical elements that may be identified in institutional statements: attribute, deontic, aim, condition, and or else. By identifying these elements, the IGT can be used to categorize institutional statements by specific rule types, and understand the intended effect of individual rules in an action situation and the combined effect of rules in the overall design of institutions [40–44]. Lien (this issue) and Siddiki et al. [45] provide high level reviews of research applications, methodological procedures, and future directions for research.

A strength and weakness of using the IGT to understand institutional change over time is that, when used to analyze changes in legislation such as the Senegalese Forest Code, it produces extremely detailed and voluminous data. Each institutional statement is parsed and then coded according to its function and its grammatical structure for each revision of the Forest Code.

When combined with theory, these data could help identify, for example, precisely what changes were made to the Forest Code to decentralize regulation and management of forests and the practical effect of these changes when analyzed through the lens of common pool resource theory [6]. However, this task is complicated by the fact that individual institutional statements are assessed and coded in isolation, making it easy to lose sight of the interactive nature of rules in each action situation and from one iteration of the Forest Code to the next.

Pairing the CIS framework with the IGT can help to overcome these challenges by focusing attention towards the institutional structure of certain “critical” action situations. Focusing IGT coding on action situations whose structures have changed over time or that have been identified as playing a critical role in outcomes of interest for a specific analysis limits the labor required to code institutional statements and the quantity of data produced. Table 1 provides an instructive example as to how the IGT can be used to identify specific changes in institutions over time, with respect to the governance of commercial exploitation of forest resources in Senegal. The IGT identifies how institutional changes marking the move from pre-decentralization to post-decentralization reflect differences in position and choice rules. The post-decentralization rules establish a position for local authorities in forest planning and decision-making and a two-stage process for planning and issuing permits. Prior to decentralization, commercial exploitation was controlled by state representatives, who held permitting authority [22]. Following decentralization, forest planning responsibilities shifted to local authorities but subject to certain constraints. Local authorities were permitted, but not required, to develop local forest management plans, allowing for local control of forest resources. These plans were, however, subject to approval for from state representatives. The permitting process for commercial exploitation follows a similar two-stage process (provided that local authorities have received approval for their management plan) in which commercial operators are required to obtain permission from local authorities and permits from state representatives.

The resulting outcomes – namely the development and approval of only limited number of local forest management plans – suggests that, although position rules may have created a place for local actors in forest management, the way these position rules were paired with choice rules may have simultaneously eroded opportunities or incentives for these actors to invest in developing management plans. Local forest management plans are subject to state approval, allowing state actors to retain influence over local forest planning. As a result, decentralization had little *de facto* impact on the ways in which forests were managed in Senegal. Without the IGT, it would be difficult to tease out the relationship between position rules and choice rules and their effect on outcomes in such critical action situations.

Table 1: Analyzing institutional change using the institutional grammar tool by comparing rules for commercial exploitation of forest resources in Senegal prior to and after decentralization.

Action Situation: Issuance of permits for commercial exploitation of forest resources			
Summary of Pre-decentralization Rules	Rule Types	Deontic	Practical effect of rules in action situation
Article D. 38- In the national domain no exploitation of forest products for the purposes of a commercial operation may take place without obtaining a permit defined in articles below	Choice rule: requires a specific action of those seeking to exploit forest resources in order to do so legally	MUST: a permit is required	The combination of choice and position rules establishes that all actors seeking to legally exploit forest resources must obtain a permit from the chiefs of inspection prior to carrying out and exploitation activities; chiefs of inspection are granted discretion to grant permits and are state level positions.
Article D. 41- Cutting permits are granted by the chiefs of inspection for the forest sector for the exploitation of timber, firewood, charcoal and accessory products	Choice rule: the chiefs of inspection may grant permits Position rule: assigns the chief of inspection to the role of granting permits	MAY: granting of a permit is not explicitly required	
Summary of Post-decentralization Rules	Rule Types	Deontic	Practical effect of rules in action situation
Art. L.7. - The exercise of the powers that the State has transferred to forests and forest lands from the national domain to the local authorities, as well as the resulting obligation for them, are specified for each community concerned in a forest management plan approved by the State representative.	Choice rules: Local authorities may develop forest management plans State representatives may approve forest management plans developed by local authorities Position rules: Assigns roles for both state representatives and local authorities	MAY: local authorities are allowed to develop forest plans, but are not required by law to do so MAY: state authorities are granted the power to approve local forest management plans, but are not required by law to do so	The combination of choice and position rules establishes that local authorities may develop forest management plans that are then reviewed and approved at the discretion of state-level authorities; there is no requirement that state-level authorities accept local management plans, providing them with de facto veto power over local forest management. This institutional arrangement may undermine the goal of forest management decentralization.

2.3. Power in Polycentric Governance Approach

The Power in Polycentric Governance (PPG) approach [46] builds upon the institutional grammar tool and CIS framework, by mapping how the contextual drivers of complex environmental governance regimes influence regime structure and effectiveness over time. The structure of an environmental regime can be understood as the complex of institutions, actors and their interactions. Regime effectiveness is the ability of instruments and actors to achieve the stated aims of the regime [46, 47]. Renewed interest in complex environmental governance has been driven by the realisation that large-scale problems often cannot be achieved by a single regime [48-51]. However, most early studies concentrated on the complexity of governance structure, as determined by the density of, and relationships between, key actors and institutions. Structural density was assumed to build robustness in a system (through greater popular support, reduced risk of regulatory capture, local experimentation, multiscale fit, and multiple checks and balances). In seeking to understand structural density (whether through networks, scale-bridging, or coordination), polycentricity was often implicitly portrayed as static. Recent studies have, however, paid increasing attention to historic institutional context and therefore the dynamic character of polycentricity [52]. In addition, limited attention has been paid to the role of power and politics in the system, and indeed to the overall effectiveness of the system over time. By linking contextual dynamics to changes in governance systems and policy outcomes over time, PPG adds historical and political richness to more variable and process-oriented approaches. Indeed, in *Making Policy in a Complex World*, Cairney et al. [53] recommend combining IAD and PPG approaches.

Following previous research in historical institutionalism, the PPG approach is dependent upon in-depth fieldwork (combining actor interviews, analyses of primary and secondary documents, and direct participant observation) to build rich and detailed analyses of the institutional design of governance systems, the actions and interactions of actors involved, and the outcomes of their interactions. Such fieldwork is time intensive and best performed in small-n comparative settings or critical cases [54]. Although the approach has been traditionally qualitative, the current “golden era” of online archiving is making powerful quantitative analysis possible too (e.g. of organisational annual reports and other records which provide participation data, data on the receipt and distribution of fiscal resources, employee and budget numbers, personnel data, media reports, etc.) [55]. The PPG approach can be conducted in two ways. First, analysts can use an inductive/interpretative approach by developing new and rich descriptions of the actors, institutions, relationships, and outcomes [56]. Alternatively, the approach can be guided by established research frameworks, such as theories of policy change [47] or typologies of power [55]. For example, Morrison’s [46] study of the Great Barrier Reef governance system was guided by theories of policy layering (the introduction of new policy alongside existing policy [57]), path dependency and drift to understand the evolution of decisions and power relations over 40 years. Regime drift, whereby regime structure remains constant in the face of significant contextual shifts [58], was particularly evident in the case of the Great Barrier Reef, where the stability of the governance system masked drift precipitated by a suite of multiscale drivers, such as significant increases in shipping in the region. Subsequent work has categorised those power relations according to formal intent (power by design), local discretion (pragmatic or discretionary power), and discourse control (framing power) [55]

To provide an example of the PPG approach in use, we draw on Ribot et al.'s [22] description of forest governance in Senegal from 1993 to 2001 to assess the influence of decentralisation reforms on regime structure and effectiveness (Fig 2). Guided by established conceptualisations of decentralisation, namely that two fundamental characteristics of decentralization are downward accountability and the discretionary power of local authorities [22], we interpret regime effectiveness in this example as the level to which the regime achieves these governance characteristics. Discretionary power of local authorities relates to their level of autonomy in making and implementing decisions related to the management and use of local forest resources [14]. Despite the implementation of the forest code promoting "participation" of rural councils in 1993 and the forestry decentralisation law in 1998, there was little increase in regime effectiveness (Fig 2A), with central government actors (minister of forests, forestry service and agents) retaining the core of the polycentric regime and informal power relationships between central, local and international elites (e.g. commercial forestry merchants and international NGOs) retaining considerable influence (Fig 2B). Local authorities' (rural and regional councils, local communities) discretionary power remained limited even after the implementation of the 1998 decentralisation law that gave rural councils the right to stop production within their jurisdiction. Central government actors retained decision-making control (Fig 2B) through restricting the influence of local stakeholders' newly acquired right to develop management plans by requiring that they be approved by the forestry service. Further, Ribot et al. [22] reported that under pressure from central government, local authorities did not exercise their rights to stop commercial production (even when called for by those who elected them), ensuring the regime continued to be characterised by strong upward accountability (Fig 2A). Despite gradual layering of decentralisation policy (Fig 2A), the regime's structure and the composition and relative power of actors (Fig 2B) remained fairly intact. By enabling depiction of regime structure and effectiveness, and the power and influence exercised by the various actors over time, the PPG approach offers a means to assess and depict the separation between decentralisation on paper and in practice with respect to Senegal's forestry governance.

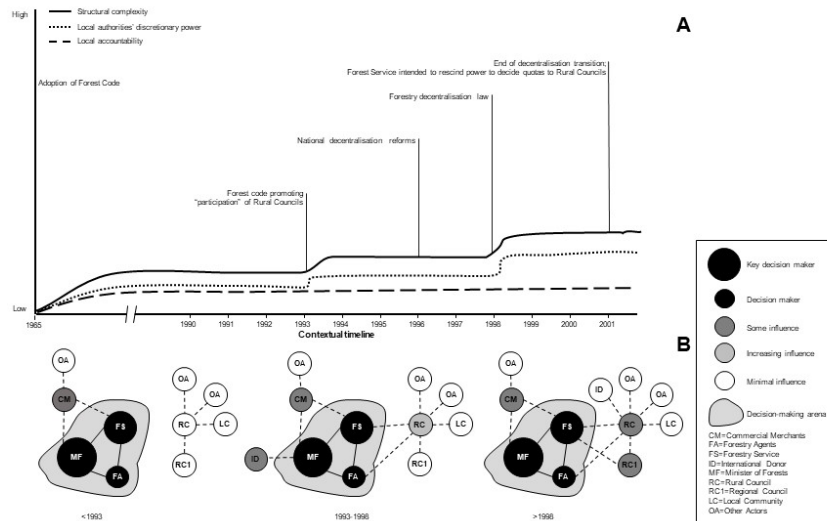


Figure 2. Analysis of the Senegalese forest governance regime over a decade of decentralisation reforms using a Power in Polycentric Governance approach [46], including key changes to regime structure complexity and effectiveness (A) and changing regime structure (B). Regime effectiveness relates to level of achievement of the stated goals of the regime, which, in this case, was decentralisation, and is thus, depicted here with respect to two core aspects of such governance reforms: local authorities' discretionary powers and downward accountability. Note that the y-axis in A refers to the level of structural complexity, local authorities' discretionary powers and downward accountability

3. Conclusions

The governance of environmental sustainability is increasingly complex due to context-dependent relationships [10], interactions [59], cross-scale dynamics [60] and social-ecological feedbacks [61]. Despite these challenges, a large and growing body of knowledge has developed concerning the critical ingredients of effective environmental governance [7, 30, 62]. This knowledge is, however, of limited utility without a similarly robust body of evidence describing the conditions and processes related to institutional change over time. The three advances discussed in this paper are important because they encourage analysts to systematically define, trace, and possibly predict institutional change in complex SESs. The institutional grammar tool provides a systematic approach for coding institutional arrangements and tracking changes in the structure and composition of rules. The CIS framework, meanwhile, provides a general tool for integrating variable-oriented and process-oriented research to understand the conditions and processes by which actors are able to overcome historical efforts to restrict local autonomy to exert control over natural resources, or alternatively the strategies that external actors exploit to retain control. Finally, the power in polycentric governance approach facilitates an understanding of the evolution of complex environmental governance systems, by tracing changes in regime structure and the power relations that underpin them over time. Together, these approaches advance our understanding of institutional past, present and future, a task that is increasingly essential to moving the field forward in the current era of governing rapid anthropogenic change.

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