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Synthesizing Archetypes of Social-Ecological Systems: Identifying Common Building Blocks

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Received: 27 February 2024 | **Revised:** 26 June 2025 | **Accepted:** 30 June 2025

Funding: Dr. Elke Kellner acknowledges financial support from the Horizon 2020 MSCA-IF-2020 (Grant no. 101027966).

Keywords: archetype analysis | knowledge cumulation | middle-range theories | model-centred meta-analysis | natural resources | social-ecological systems (SES) framework

ABSTRACT

A growing number of studies apply the social-ecological systems (SES) framework with its standardized set of variables to examine place-based environmental governance. Yet, due to the wide diversity of social-ecological systems, a general theory about how variables interact—and systems can be governed—lacks empirical support. Despite many case studies, knowledge cumulation is hindered by data heterogeneity, and by the difficulties with synthesizing a large number of cases into middle-range theories, possibly understood as re-occurring patterns of the larger theoretical puzzle of environmental governance. Thus, this paper aims to cumulate knowledge by identifying repeating configurations of variables across 71 models from SES framework case studies using archetype analysis. We propose a building-blocks approach to identify eight archetypes, each characterized by a triad (presence of three variables), an explanation of this triad, and a qualitative characterization with cases which exemplify them. The triads relate to, for example: shared operational agency; small households in remote, inaccessible places; property and accountability; or formal investment conditions. We show how a relatively small set of triads can be combined in various ways to represent a larger diversity of SES, and illustrate this by re-visiting several cases. We argue that identifying these recurring archetypes advances the field because it allows scholars to focus their theorizing and empirical research around a known set of triads. More broadly, the paper contributes to advancing empirically supported claims about SES and environmental governance, new uses of the SES framework, and techniques for knowledge cumulation using archetype analysis.

1 | Introduction

Over the years, scholars have studied a wide range of social-ecological systems (SES; Cox 2014; Cox et al. 2010; Nagel and Partelow 2022; Partelow 2018; Villamayor-Tomas et al. 2020). Despite high-level aspirations for theory development based on comparative analyses with common frameworks (e.g., Ostrom 1990), moving towards general level claims on collective action or environmental governance has yet to specify variable-level patterns of interactions that reliably relate to outcomes (Partelow et al. 2020). Moreover, it has been argued that such a general theory is neither possible nor adequate for endorsing the diversity of SES (Cox 2008; Ostrom et al. 2007; Young et al. 2006). As a result, some have questioned the

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practical and theoretical utility of this line of research—a challenge for SES research shared with broader scholarship on environmental governance (Hofmann et al. 2025; Newig and Rose 2025). Others have argued that at least middle-range theories (Merton 1968) might be the way forward (Magliocca et al. 2018; Meyfroidt et al. 2018). Middle-range theories do not hold in all cases but are supposed to hold under well-specified conditions in groups of cases. This might avoid the 'idiographic trap', which considers each SES as an utterly unique state of affairs, preventing generalization across cases (Eisenack et al. 2019). Nonetheless, the use of middle-range theories is also challenging given the need for consistent knowledge cumulation methods. They should be context and data-adaptable while also providing a conceptual frame for interpreting identified patterns.

In this paper, we aim to advance knowledge cumulation by combining archetype analysis with a model-centered meta-analysis of peer-reviewed articles which use the SES framework. We quantitatively identify triads—configurations of three variables—within models of social-ecological system interactions. This intends to contribute to developing systematic methods for knowledge cumulation in sustainability studies (Newig and Rose 2020). When doing single case studies, for instance, one can cumulate knowledge by referring to other case studies or theories and by scrutinizing how far those other insights are confirmed, rejected, or qualified. However, if such comparisons are not structured in a common way, knowledge can remain scattered over a broad set of diverse and disjointed publications, relegating SES scholarship to the status of a "fragmented ad-hocracy" (Khmara 2024; Whitley 2006). Cumulation then becomes less visible, less effective, or even impossible. Pauliuk (2020) questions whether this research mode can lead to advances with the speed needed to cope with ever-pressing sustainability challenges. We need to pursue methodological and conceptual advances—for example, those offered by archetype analysis.

Several contributions in this Special Issue aim to conceptualize and systematically assess knowledge cumulation in the broader field of environmental governance, policy and planning (Hofmann et al. 2025; Newig and Rose 2025; Wood et al. 2025). We hereby explore the potential of archetype analysis to that end: a method that "investigates recurrent patterns [...] of interest [...] to identify multiple models that explain the phenomenon under particular conditions" (Oberlack et al. 2019). Importantly, archetype analysis aims to identify building-blocks. Building-blocks are recurring patterns which can be re-combined as part of larger system analyses. The promise is that a large set of middle-range theories, all characterized by variable configurations, can be reduced to a smaller and more manageable list of archetypes which can then be used as building-blocks.

We use Ostrom's SES framework (McGinnis and Ostrom 2014; Ostrom 2007) because it offers a comprehensive list of variables that are used in many case studies in the existing literature. This allows us to integrate evidence across multiple studies and contexts. Previously, syntheses have identified frequent SES variables (Partelow 2018; Villamayor-Tomas et al. 2020), and identified frequent dyads and triads of those variables (Partelow et al. 2024). Such configurations can be considered as repeatedly occurring pieces of the larger theoretical puzzle in environmental governance. What previous studies have not obtained are common configurations which also consider how the variables are related, and how they can be combined as building-blocks. Consequently, further research is required to: (1) select the 'best' configurations from the large number of variable configurations which appear in case studies; (2) describe configurations of variables also qualitatively; (3) scrutinize whether those configurations align with existing theories; (4) clarify how such configurations can indeed be understood as building-blocks which can be combined in different ways.

To close part of this gap, we identify (as outlined in the following methodological section) a set of triads which covers the models in an optimal way. Here, we focus on triads in the sense that the variables are present in the models. In the results section, we assess their case-level relevance and start to explore their theoretical salience. The qualitative part of our analysis also provides examples for how the variables are interlinked. Eight triads pass our tests, qualifying them as archetypes. Subsequently, we show examples of how they can be combined as building-blocks, and conclude with discussing the promise of the approach to cumulate knowledge.

2 | Material and Methods

We analyse a corpus of 125 "models" extracted from 30 publications which apply the SES framework (see Villamayor-Tomas et al. 2020; and Appendix A for more methodological details). Coding followed a model-centred meta-analysis approach (Rudel 2008), where papers are broken down into models. Models are text segments that contain statements about results from empirical case studies, for instance causal relations among variables, but also explanations about other relations among variables. A single paper can contain one or multiple models. As common in meta-analyses, we do not question the validity of the models which appeared in peer-reviewed papers. The main contribution of the present paper is not the creation of the data. The methodology for data collection has been well described and discussed in relation to benefits and challenges in a prior publication (Villamayor-Tomas et al. 2020), which we use as the basis to develop the novel approach to data analysis here. For our present paper, the data for the quantitative part of the analysis is the cross-tabulation of the models with the presence or absence of the 54 variables of the SES framework (binary, not by polarity or value, and not a direction of causality among the variables). Please consult the Appendix A for the table of variables. Each model can be coded by a specific number of variables. We thus opt to code the models with a framework which is used by all the studies themselves, which eases consistency and interpretation. We use those 71 models which were coded by at least one outcome variable (social, ecological, or externalities), because they were coded with more rigorous inter-rater checks. Yet, we do not use the outcome variables for the further analysis (see Section 4, and Partelow et al. (2024) for an analysis of the outcome variables). For the qualitative part of the analysis (further details below), the full texts of the papers are used.

The archetype approach was used for data analysis. Generally, archetypes are characterized by three elements (Eisenack

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et al. 2019): (i) a configuration (here: a triad of second-tier SES variables), (ii) the models where the configuration is present, and (iii) an explanation which rationalizes the presence of the configuration in the models. This paper focuses on elements (i) and (ii) and starts scrutinizing element (iii). Archetype analysis is not intended to produce a uniform theory, but a set of multiple archetypes which reflect the diversity of the cases studied.

In the quantitative part, we address the first element (i) with a formal concept analysis (FCA; Ganter et al. 2005a; see Appendix A for more details). This computational method yields the list of all so-called 'concepts' which are hidden in the binary data, as shown in other publications (e.g., Chen et al. 2023; Oberlack and Eisenack 2018; Oberlack et al. 2016; Wang and Tan 2020; Wang et al. 2019). Each concept is characterized by two ingredients. The first is a configuration of variables ('intension' in FCA jargon), in our study this could be, for example, Leadership (A5)-Knowledge of SES (A7)-Operational rules (GS5). The second ingredient (the 'extension') is the set of all models where the configuration is present (exactly those variables, or possibly together with further variables). The extension addresses element (ii) quantitatively. The algorithms of FCA determine configurations which are potentially suitable for being archetypes, because they are maximal. This means if, say, two variables always occur together with a third, the third variable will also be part of the concept. It is important to note that FCA classifies models just by the variables they feature. To rationalize the concepts, one needs to go back to the case studies, as we do in the qualitative part (see below). However, we first need to deal with the issue that there are often many such concepts (345 in our study). Some are quite simple (just one variable), others are very complicated (some with more than 20 variables) in our data (see Appendix A for more details of the FCA results). Thus, further criteria to select configurations are needed for identifying archetypes. We adapt a semi-quantitative procedure suggested elsewhere (Harmáčková et al. 2025; Eisenack and Wang 2025), which includes to filter the algorithm's output with concepts only containing three variables, and the following basic ideas.

First, some configurations might be surprising, while others are less so. One way to quantify this is the lift metric, which was developed for association rules mining (e.g., McNicholas et al. 2008). If a configuration consists of variables which are frequent in the data anyway, it would be of no surprise if they also occur frequently together. For a configuration of three variables (triad), let p_A denote the relative frequency of variable A, p_B, p_C the relative frequency of variable B and C, and p_{ABC} the relative frequency of all three variables occurring together. Then, the lift is defined by

$$lift(ABC) = \frac{p_{ABC}}{p_A \cdot p_B \cdot p_C} ,$$

which is always non-negative. If $lift = 1$, the configuration appears as frequently as expected. Higher lift means that it appears more frequently than expected. Thus, we might prefer configurations with a high lift.

Second, we select configurations from the list of concepts which are jointly capable of covering a large share of all models. Obviously, admitting a larger list would lead to covering more models. To avoid having one individual configuration for each model (the idiographic trap), we employ a cut-off criterion to stop selecting a further concept if it only leads to covering one further model (following a criterion by Eisenack and Wang 2025). Moreover, coverage depends on whether we select simpler configurations (high coverage) or more complicated configurations. If we would choose only configurations of, say, 10 variables, all models coded with nine or fewer variables cannot be covered. To deal with this trade-off, we employ an algorithm as described by Harmáčková et al. (2025). If we only admit concepts with a certain number of variables (3 in our case), and suppose we admit selections of N concepts, how can we find those N concepts which yield the highest possible coverage? Technically speaking, this is done by an algorithm that solves a maximization problem with set operations in the maximand and the constraint (see Appendix A). Due to this procedure, it can turn out that the N most frequent triads do not maximize coverage when they overlap. Thus, we get optimal selections for each possible N and choose it so large that we cover two additional models at the margin.

While Partelow et al. (2024) consider configurations of two variables (dyads) and three variables (triads), we focus on triads in this paper. With triads, richer and more detailed theories can be considered. Our procedure would also work with configurations of four or more variables, but we do not do this because theories with more than three variables are less parsimonious and more complicated to convey. Yet, this does not mean that we disregard models with more variables, since they also contain triads as subsets.

For the qualitative part, we inspect all triads from the optimal selection in detail. For this purpose, we split the triads among the co-authors; then, the first author cross-checked reports from the co-authors and resolved doubts collaboratively if necessary for a final decision. This collaborative approach is chosen over a more quantitative inter-reliability approach (Krippendorff 2011), given the rather reduced number of triads selected (8). To address the second element (ii) qualitatively, we go back to the papers where models with the triads stem from and re-attribute their contextual meaning (see Section 3). At this stage, co-authors are encouraged to identify narratives that connect the variables in the articles and do so by limiting their own interpretations of the text. This step is important because the original models do not always specify causal relationships between all variables (Villamayor-Tomas et al. 2020). To address the third element (iii), we aim to come up with a theoretical rationalization that connects the narratives with existing theory. Here, co-authors were encouraged to refer to theory typically used in SES framework applications, that is, commons and collective action theory (Agrawal 2001; Ostrom et al. 1994; Partelow 2018; Poteete et al. 2010; Schlager and Villamayor-Tomas 2023) of which all co-authors are experts. In some occasions, the articles also included references to a theory, which facilitated the exercise. Thus, while the quantitative part focuses on the presence of interlinked variables, the qualitative part provides examples of how the variables are interlinked and possible outcomes. If we would not have been able to provide such a characterization for one triad, we would have deleted it from the list. All optimal triads together—which pass this test—are then called a suite of archetypes, our main result.

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TABLE 1 | Candidate archetypes (see Appendix A for complete codes of the variables).

Archetype	Triad	Frequency	Lift
Archetype 1	Leadership (A5)-Knowledge of SES (A7)-Operational rules (GS5)	9	4.09
Archetype 2	Social capital (A6)-Property-rights (GS4)-Operational rules (GS5)	10	3.06
Archetype 3	Leadership (A5)-Knowledge of SES (A7)-Network structure (GS3)	7	6.85
Archetype 4	Leadership (A5)-Trust (A6)-Resource dependence (A8)	12	5.17
Archetype 5	Socio-eco. attributes (A2)-Social capital (A6)-Property-rights (GS4)	8	5.72
Archetype 6	Number of actors (A1)-Storage characteristics (RS8)-Location (RS9)	4	28.0
Archetype 7	Investment activities (I5)-Operational rules (GS5)-Other governmental systems (S4)	5	9.19
Archetype 8	Harvesting (I1)-Property-rights (GS4)-Value of resource units (RU4)	3	6.43

The last step of our analysis tests the building-blocks idea of archetype analysis. This means that archetypes are not mutually exclusive. Single models are often characterized by multiple archetypes. Building-blocks can have the advantage that more complicated models are broken down into simpler archetypes. There is also an economizing principle, since a small number of building-blocks can represent a broad diversity of models, due to the large number of possible combinations of those building-blocks. Thus, we select models with two or three archetypes and inspect those papers in detail to scrutinize how the archetypes relate to each other.

3 | Results

We are not primarily interested in the most frequent triads (see Appendix A for more details), but want to have a manageable number of triads which jointly cover many models (see Section 2). According to our criteria (see Section 2), eight triads jointly maximize coverage, at 36 models (88% of the models which are coded with at least three variables). If we would require only 2/3 of the models to be covered, five triads would be sufficient. Yet, we deem it as a loss of the analysis, if we lose 21% of the models just for 'saving' three triads.

While a selection of 8 triads maximizes joint coverage, there are four different ways to select 8 triads in this way. This is common for such optimization problems. A closer inspection of the four optima reveals, however, that they are quite similar. They all contain the same seven triads, and only differ in the one remaining triad. For instance, they all contain the most frequent triad (A5-A6-A8), but none of them contains the second most frequent triad (A7-GS5-GS8; see Appendix A). We need some of the less frequent triads to cover 'gaps' which are left open by the more frequent ones. All lift values of included triads are considerably above unity, so they appear in the data much more frequently than by chance. We could have chosen the eighth triad among the four possibilities by lift, but we opted to choose Archetype 8[1]. We do this for several reasons. First, its lift is at least sufficiently large. Then, it is interesting that an infrequent triad can cover what is not covered by the other triads (i.e., it fills a theoretical gap in the content covered). A close inspection of the data shows that this triad does overlap with the others in just one model. Appearing nearly in isolation eases its interpretation when going back to the original publications. In the following, we do exactly this for the eight selected optimal triads. Thus, the subsequent paragraphs are meant to test the salience of each triad in terms of general considerations and case-level examples. Based on the scrutiny of these paragraphs, we argue that the selected triads (see Table 1) can be considered as archetypes, but we first call them candidates before they pass the next test.

3.1 | Archetypes

All triads passed the qualitative test, that is, co-authors found narratives that fit existing theory. The following subsections offer qualitative characterizations of each triad from a theoretical perspective, and examples from the original cases where they appear (see Table 2 for a brief summary of each archetype based on qualitative author interpretations of the case studies).

3.1.1 | Archetype 1: Shared Operational Agency

This triad is built of actor and governance systems variables. It relates to leadership (A5) with actors' knowledge of the SES (A7) and operational rules (GS5). The triad is distributed over 6 papers (Begossi et al. 2012; Carrillo et al. 2019; Duff et al. 2017; Epstein et al. 2014; Partelow and Boda 2015; Partelow et al. 2018). From the theoretical perspective, the triad characterizes an important set of features driving community-based collective action. Strong leadership coupled with sufficient knowledge of SES dynamics (whether formal scientific or informal local) can positively influence effective operational rule development (if positively reinforcing). On the other hand, weak leadership and low knowledge can hinder rule development (if negatively reinforcing). We observe examples of both positive and negative qualitative cases in our models. Carrillo et al. (2019) show in two case studies that although leadership existed to establish responsible fishing areas, continued leadership over time and low scientific and local knowledge led to ineffective rules in the long term (also considering other variables). In contrast, Epstein et al. (2014) and Partelow and Boda (2015) both show that strong leadership, high scientific knowledge and effective operational rules are positively related.

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TABLE 2 | A brief overview of the archetypes with simplified descriptions.

Archetype	Label	Description
Archetype 1	Shared operational agency	Strong leadership coupled with sufficient knowledge can have a reinforcing effect on the development of appropriate operational rules, while weak leadership and lack of knowledge can hinder rule development.
Archetype 2	Property and accountability	Unclear property-rights and ownership among local actors can lead to ambiguities in operating resource management, and trust cannot compensate for that if it is limited.
Archetype 3	Leadership structure	The (de)centralization of governance strongly shapes how leadership plays out. For top-down arrangements, the implications for the resource (but also the distribution of benefits among resource users) also rest upon the strength of monitoring. The latter might be weak by leaders' design, but also be weak if local networks are fragile.
Archetype 4	Community self-efficacy	Social dynamics, motivations and capacities play a strong role in shaping community-based natural resource management. Resource dependence is a strong reason for moving away from an inefficient open access regime and to build relationships with other users facing similar conditions and constraints. If trust can be established from this process, then effective leadership can motivate collective action.
Archetype 5	Informal collective decisions	The ability to work together is strongly shaped by informal systems of social norms and trust within a local community, which functions when resources and property-rights are not disputed. However, non-agreement and low levels of trust and social capital can lead to conflicts.
Archetype 6	Small households in remote, inaccessible places	Bio-physical features of the area such as topography play out particularly if communities are small and not strongly connected. Land-use patterns are adjusted to costs (e.g., accessibility of land), needs (e.g., number of children), and (limited) market access.
Archetype 7	Formal investment conditions	Investment is strongly shaped by institutional barriers (formal judicial, legislative and executive factors) which also undermine community values and motivations for enabling collective action locally.
Archetype 8	Resource quality and allocation	Establishment of clear property-rights influences who has access to, or makes decisions regarding harvesting of a resource, while the real or perceived economic value of the resource units further influences decisions regarding how much or which resource units are harvested.

Another example is Duff et al. (2017), which explore the conditions that contribute to sustainable agricultural land management, with an eye on the role of stewardship networks. They show through the case of the Healthy Grown Potato Program in Wisconsin (US) the importance of early committed farmers (A5), an enduring vision that is shared among network members (A7) and the existence of individualized conservation implementation plans (GS5). Early committed farmers were in a privileged position to lead stewardship networks due to their unique capacity (information, tacit know-how) to address the challenges of integrating conservation and agricultural production demands. They contributed to the emergence of a shared vision about conservation needs among farmers, and the elaboration of farm-level conservation plans. The existence of a shared vision made conservation standards clear and contributed to their tailoring at the farm level. These individualized conservation plans ultimately contributed to improved ecological outcomes.

3.1.2 | Archetype 2: Property and Accountability

This triad is built of actor and governance systems variables. The second-tier variables are property-rights systems (GS4), operational rules (GS5) and norms (trust-reciprocity)/social capital (A6). It is distributed over 6 papers (Bauwens et al. 2016; Begossi et al. 2012; Carrillo et al. 2019; Davenport et al. 2016; Naiga et al. 2015; Partelow et al. 2018). For example, Naiga et al. (2015) analyze the factors which lead to challenges hampering long-term access to safe water in rural Uganda after a major policy shift from a supply-driven to a demand-driven approach in rural water provision since 1990. The results illustrate how the inability of multiple actors (A6) to cope with external policy change can hinder local water governance. In particular, the pertinent ambiguity of property rights between state authorities and the water users (GS5) resulted in a lack of perceived ownership on the local level (GS4). This impacted local collective action necessary for sustained access to safe water.

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3.1.3 | Archetype 3: Leadership Structure

This triad consists of the second-tier variables leadership (A5), knowledge of SES (A7) and network structure (GS3); see also Table 2. It appears in 7 models, distributed over 6 papers (Basurto et al. 2013; Begossi et al. 2012; Epstein et al. 2014; Fleischman et al. 2014; Partelow and Boda 2015; Partelow et al. 2018). Fleischman et al. (2014) evaluate the utility of common-pool resource theory in large-scale management contexts with deforestation. As they illustrate, centralized government (GS3) and strong leadership in the form of an authoritarian regime (i.e., that of General Suharto in Indonesia) can be counterproductive if driven by political and economic agendas that understand forests as resources to be exploited by all means. As illustrated in the article, General Suharto was the person who, along with political and corporate interests (A5), designed a system with the intention of maximizing short-term revenues at the expense of sustainability. Combined with a lack of monitoring and sanctioning of forest extraction (A7) and the undermining of local community rights, deforestation scaled up further.

3.1.4 | Archetype 4: Community Self-Efficacy

Here, only actor-related variables appear (see Table 2), on the second-tier leadership (A5), trust (A6) and resource dependence (A8). It is distributed over 8 papers (Basurto and Ostrom 2009; Begossi et al. 2012; Carrillo et al. 2019; London et al. 2017; Nagendra and Ostrom 2014; Oviedo and Bursztyn 2016; Partelow et al. 2018; Williams and Tai 2016). In their study of community-based fishery management in Mexico, Basurto and Ostrom (2009) highlight the costs of self-organization as a central challenge for a community of resource users trying to move away from an open-access regime. A set of factors, they show, contributes to lowering said costs, including leadership (A5), trust (A6) and resource dependence (A8). These community attributes distinguish successfully self-organizing communities from communities that ended up overexploiting their fishery because they could act as positively reinforcing social dynamics. Similarly, London et al. (2017) highlight the role of trust (A6) for successful community-based resource management in an artisanal fishing community in Argentina. Workshops and interviews were conducted in the context of a large, interdisciplinary research project aiming at characterizing a specific social-ecological system along Ostrom's SES framework and map the actors at play. In the process, leadership (A5) and resource dependence (A8) emerged as key variables determining trust within the fishery community.

3.1.5 | Archetype 5: Informal Collective Decisions

The triad is compiled of socio-economic attributes (A2), norms (trust-reciprocity)/social capital (A6) and property-rights systems (GS4). It appears in 8 models, distributed over 6 papers (Bauwens et al. 2016; Begossi et al. 2012; Carrillo et al. 2019; Ernst et al. 2013; Hileman et al. 2016; Partelow et al. 2018). For example, Ernst et al. (2013) explore factors that contribute to sustainable lobster fishing, which is the main source of income for the people from the Juan Fernandez Archipelago (Chile). The analysis shows that the resource is regulated by an informal but effective sea tenure system (GS4) of a homogeneous community (A2) which shares norms and substantial social capital (A6). This has sustained the economy of the Juan Fernandez Islands for over a century. Hileman et al. (2016) analyze the factors leading to conflicts in 10 cases of water resource management in rural Central America to observe four types of conflicts. Disputes over property rights, such as missing legal claims to land or access rights to water sources and infrastructure (GS4), socio-economic attributes of users like varying interests of stakeholders (A2) and low levels of trust and social capital to pool resources (A6) are among the most common causes for conflicts. The triad appeared particularly in two conflict types: acquiring and protecting water sources and passing infrastructure across private lands. Hence, water resource conflicts are rarely the result of a small set of variables in isolation.

3.1.6 | Archetype 6: Small Households in Remote, Inaccessible Places

The second-tier variables are the number of actors (A1) to the storage characteristics (RS8) and location (RS9) of the resource system, see Table 2. The triad appears in 2 papers (Begossi et al. 2012; Sharma et al. 2016), and has a very high lift. For example, Sharma et al. (2016) explored social-ecological variables explaining diverging land cover outcomes between indigenous communities in Eastern Panama. Their findings suggest that three land use outcomes have been shaped by household size and number of children (A1), topography in terms of slope and elevation (RS8) and distance to highway (RS9). Varying combinations of these attributes influenced whether land was primarily converted to cropland, pasture or maintained as forest. Forests are found in more remote areas with inaccessible topography; cropland is highest in less remote areas with large household sizes, while pasture is most common in less remote areas with more accessible topography and households with fewer children.

3.1.7 | Archetype 7: Formal Investment Conditions

The triad consists of investment activities (I5), operational rules (GS5) and other governmental systems (S4); see Table 2. This triad is distributed over 2 papers (Bauwens et al. 2016; Begossi et al. 2012), and also has a quite high lift. In Belgium, studied by Bauwens et al. (2016), wind energy cooperatives have faced challenging institutional barriers. The scarcity of suitable sites, the increasing number of wind developers and the zoning policies (GS5) have created a highly competitive environment for the few suitable locations available. Formal policies as rules can undermine efforts by cooperatives who lack the time and resources (I5) to act as fast as larger-scale producers. Judicial appeals (S4) are another tangential governance system that can intervene, for example, to be used as a tool by more powerful turbine owners against cooperatives. As such, fewer new community wind projects exist because the institutional factors are not tailored to cooperative models, but rather set up to favor larger energy companies and turbine owners.

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3.1.8 | Archetype 8: Resource Quality and Allocation

This triad consists of the combination of harvesting (I1), property rights (GS4) and value of resource units (RU4); see Table 2. It is distributed over 3 papers (Begossi et al. 2012; Bennett and Gosnell 2015; Sharma et al. 2016). For instance, in comparing social-ecological factors explaining land cover outcomes in two eastern Panama communities, Sharma et al. (2016) used process tracing to assess the historical factors that have contributed to deforestation and the current land cover landscape. First, pre-settlement timber extraction in the region led to a perceived reduced economic value (RU4) of already degraded forests, increasing incentives for forest clearing (I1). Governance decisions to distribute unused lands to previously landless families (GS4) for subsistence use further led to increased forest loss, particularly when the value of degraded forest (RU4) on these lands was perceived to be low. Timber extraction from large-scale logging operations (I1) further shaped historic changes in land cover.

3.2 | Archetypes as Building-Blocks

The previous section profiled eight archetypes. Each is described by a triad and accompanied by a theoretical description and case study examples where it is present.

Here we explore how the archetypes can be combined in different ways—as building blocks—in order to portray particular cases. Table 3 summarizes, for each possible pair of archetypes, the frequency and the lift of them jointly being present in the same model in our data.

Subsequently, we select some examples from the coded literature where two or three archetypes are combined. Example selection is based on triads occurring as pure as possible with little (or no) other variables being present because we think this is the best way to test the building-blocks approach (and to cope with space limitations) (see Appendix A for the papers where the combinations occur). This serves as an illustration (see Figure 1), but also to reflect on how the building-blocks approach can work in general.

3.2.1 | Combining Archetypes 1 and 4: "Shared Operational Agency" and "Community Self-Efficacy"

These two archetypes are combined by one specific variable (leadership, A5). They jointly appear in 4 models, so in nearly half of the models with Archetype 1 and a third of the models with Archetype 4. One of those is exemplified by Carrillo et al. (2019) who investigate how social-ecological conditions influence collective action in small-scale fisheries co-management in Costa Rica (Marine Areas of Responsible Fishing, AMPRs). In Isla Caballo, collective action is widely failing, which seems to be explained by the combination of Archetype 1 (A5-A7-GS5) and Archetype 4 (A5-A6-A8). While a shared motivation for AMPR formation was to implement rules (GS5) to restrict destructive fishing practices and perceptions of degrading fisheries (A7), resource management has actually had a negative effect on collective action due to a combination of operational rules which many fishers view as illegitimate (GS5), exacerbated by perceptions of poor leadership (A5). Thus, fish resources continue to be perceived as poorly harvested (A7). The "shared operational agency" archetype (Archetype 1) further describes the failure of collective action. Differences between government AMPR proposal and its implementation, which reduced the legitimacy of the AMPR for fishers (A6), were exacerbated by perceptions of poor leadership (A5) due to criticisms that leaders' family members preferentially avoid illegal fishing sanctions, as well as ongoing mistrust between small-scale fishers (A6), leading some fishers to leave the organization. Fishers have relatively low dependence on resources from the AMPR (A8) due to its small spatial extent, further reducing motivation to participate in

TABLE 3 | Frequency of archetype pairs which co-occur as building-blocks in single models (lift in brackets).

	1	2	3	4	5	6	7
Archetype	**A5-A7-GS5**	**A6-GS4-GS5**	**A5-A7-GS3**	**A5-A6-A8**	**A2-A6-GS4**	**A1-RS8-RS9**	**I5-GS5-S4**
2: A5-A7-GS5	3 (2.37)						
3: A5-A7-GS3	5 (5.63)	3 (3.04)					
4: A5-A6-A8	4 (2.63)	4 (2.37)	3 (2.54)				
5: A2-A6-GS4	3 (2.96)	5 (4.44)	3 (3.80)	4 (2.96)			
6: A1-RS8-RS9	1 (1.97)	1 (1.78)	1 (2.54)	1 (1.48)	1 (2.22)		
7: I5-GS5-S4	1 (1.58)	2 (2.84)	1 (2.03)	1 (1.18)	2 (3.55)	1 (3.55)	
8: I1-GS4-RU4	1 (2.63)	1 (2.37)	1 (3.38)	1 (1.97)	1 (2.96)	1 (5.92)	1 (4.73)

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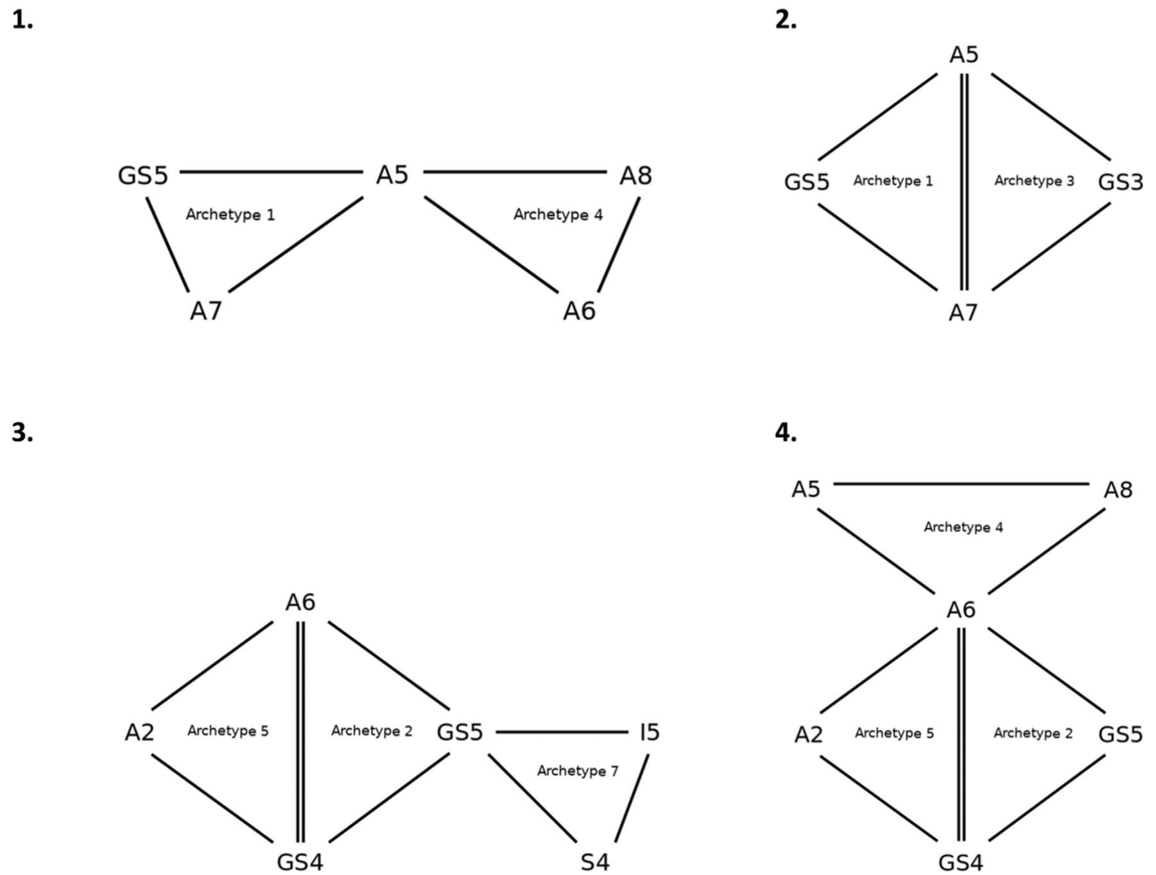

FIGURE 1 | Illustration of the four examples of combining archetypes as building blocks (for descriptions see Sections 3.2.1–3.2.4).

management and contributing to ongoing failure in collective action. We can see here two triads being present, which could be problematic even if stand-alone. However, weak leadership is a constituent of both archetypes. It follows that it might be worthwhile to test interventions which target the variable A5.

3.2.2 | Combining Archetypes 1 and 3: "Shared Operational Agency" and "Leadership Structure"

Archetype 1 and 3 occur together in five models (lift 5.63). The archetypes are connected via two variables: leadership (A5) and actors' knowledge of the SES (A7). One archetype adjoins operational rules (GS5, Archetype 1) the other, network structure (GS3, Archetype 3). As an example, Begossi et al. (2012) study biodiversity conservation and fishery management at the South-Eastern Brazilian coast of Paraty. Traditional and informal local operational rules (e.g., conservations practices and zoning rules, GS5) are in place, based on fishermen's local ecological knowledge (A7), and involving local leadership only to a limited extent (A5), and a fragile network structure (GS3) with comparatively weak communication channels. In addition, those rules are not recognized by other users and the government (A5). Other income sources like tourism or governmental payments improve, to some degree, local communities' livelihoods. This is partially based on the government's knowledge of the SES. Thus, the study reflects a quite interwoven combination of two archetypes that can have ambivalent effects. While Archetype 1, linked to traditional rules and knowledge, could in principle support conservation, it is disturbed by the problematic side of Archetype 3, linked not only to governmental rules for conservation measures but also to the economic benefits gained through fishery for the local community, which could—in principle—also enfold in a more sustainable way.

3.2.3 | Combining Archetypes 2, 5, and 7: "Property and Accountability", "Formal Investment Conditions" and "Informal Collective Decisions"

It is also possible that three archetypes work as building-blocks at the same time. The combination of Archetype 2, 5 and 7 (with a high lift of 25.21) occurs twice in our data, for instance in the paper by Bauwens et al. (2016). They show that renewable energy cooperatives face institutional barriers for establishing collaborative solutions toward low-carbon energy systems at the local level. For example, the deregulation of ownership (GS4) of wind turbines and the incapacity of municipalities to legally enforce community ownership of wind energy operations at local level (GS4) has stifled progress in Belgium. Furthermore, the socio-economic ability (A2) of populations to invest in wind energy partly explains why wind cooperatives emerge in some regions such as Germany, while not in others. Formal operational rules such as zoning policies (GS5) have created a highly competitive environment and scarcity of suitable sites. Cooperatives are often disadvantaged by such policies because they lack the time and resources (I5) to act as fast as large-scale wind power producers to scout locations and deal with administrative processes.

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Furthermore, norms in the form of local support for renewables can create momentum for kick-starting local action where it exists, but if absent can be a barrier to collective action (A6). Judicial appeals through courts have been made as another form of governance (S4), for example in Belgium, to hinder local wind energy initiatives, often in relation to modifying the ownership and participation models between citizens, municipalities and companies. In this case, we have one archetype (Archetype 2, "property and accountability") which links formal rules with attributes of the community, and is between Archetype 5 and Archetype 7. The latter two would fall apart if the problematic Archetype 2 would be resolved. Actually, Archetype 5 points at some possibilities to improve collective action, but is, in this case, not able to counter the barriers raising from "formal investment conditions".

3.2.4 | Combining Archetype 2, 4, and 5: "Property and Accountability", "Community Self-Efficacy", and "Informal Collective Decisions"

Finally, consider another instance where three archetypes are combined. Archetype 2, 4 and 5 occur together in four models (lift 21.0). One of them appears in another small-scale fisheries case from Carrillo et al. (2019). The Paquera-Tambor AMPR has had considerably more success in fostering collective action. Here the successful collective action outcomes relate to Archetype 2, Archetype 4 and Archetype 5. Clearly designated management zones assigned to different actor groups (GS4), aided by good relationships between these groups (A6), have had a positive influence on collective action, although fishing regulations are still often ignored (GS5) (Archetype 2, "property and accountability"). Strong leadership (A5) and the inclusion of non-fisheries actors due to the importance of the AMPR for marine tourism (A8) have further influenced confidence in management (A6) (Archetype 4, "community self-efficacy"). Finally, "informal collective decisions" (Archetype 5) are supported through the presence of key actors with professional training in biology and administration, combined with high investments from local actors (A2). Agreement and support (A6) for the zonal management system (GS4) have helped to further enable collective action in the AMPR. As in the last section, Archetype 2 causes a problem, but Archetype 5 is able to balance it, possibly in an interlocked way and supportive with Archetype 4. This is possible, because all three archetypes are connected via social capital variables (A6).

4 | Discussion

Overall, this paper shows that the variables of the SES framework can be used to identify an optimal selection of eight triads, which re-appear across different contexts (e.g., countries or resources). After passing the qualitative appraisal (Section 3.1), they stand out as archetypes. It is possible to meaningfully combine the archetypes like building blocks (Section 3.2).

Part of our motivation to employ an archetype analysis was to decompose a diverse set of models within case studies into building-blocks, that can be re-combined to characterize idiosyncratic conditions with a more manageable number of 'ingredients'. Importantly, we think that each archetype triad is more easily explained theoretically as an isolated unit. While the readers will judge whether the combined archetypes are theoretically consistent and complementary, we were surprised by the observed level of fit.

More generally, one can raise the question of what it actually means to combine building-blocks. We can see that there are different ways. First, it might be that two archetypes are present in parallel, with no interactions. This was not the case in our examples, but there are several instances of such a 'combination' in our data. Second, combined archetypes can be linked through one or more shared variables. This can be due to those archetypes emphasizing different nuances of the same complex, which might likely happen in papers of an epistemic community with different research interests. In addition, linking can be due to multiple mechanisms which enforce or balance each other through shared variables (as in Section 3.2.2 and 3.2.4). From an applied viewpoint, such variables might be candidates for policy or community interventions. Third, it can also happen that one archetype connects two other archetypes which would be separate otherwise (as in Section 3.2.3). The emergence or disappearance of the connecting archetype might then deeply change the evolution of the SES. There are likely more ways to combine multiple archetypes. This offers many possibilities to derive testable hypotheses or to help with case selection in future research.

Notwithstanding these findings and methodology, which is in line with quality criteria for archetype analysis (Eisenack et al. 2019; Piemontese et al. 2022), our analysis has also a number of limitations. As a meta-analysis, our findings are inherently limited by the variability in methods, transparency and general diversity in interpretive lenses across heterogenous individual studies, which makes generalization difficult. Although we do not suffer from a sampling bias (we analyzed all available models from studies using the SES framework which report on outcomes), our findings might synthesize biases from the author's theoretical or normative positions. Here, this might be due to typical research interests by scholars using the SES, which might explain that actor-related variables are more frequent than those related to resource units (see Partelow et al. 2024). This is a common limitation to meta-analyses. Moreover, the archetypes presented here offer a relatively static representation of factors that co-occur in cases, neglecting the dynamic and often interconnected processes by which these factors develop. As a result, future studies should consider exploring the processes by which these and other archetypes develop in SESs over time (cf. Orozco et al. 2024; Ekstrom et al. 2025). Future studies could also address external validity. Do we find the identified archetypes also in other papers or in future papers using the SES framework? And do they appear in other combinations? Here, the eight archetypes can serve as starting hypotheses for the next wave of synthesis.

We carefully considered the optimal selection of triads, instead of, for example, quadrads or larger configurations (see Section 2). Requiring quadrads would considerably reduce the share of the literature contained in our analysis and increase the interpretive complexity. For example, it would be unclear if

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quadrads are unique configurations or simply two dyad building blocks combined. To accurately test our hypotheses, a foundational assessment of triads was necessary to confirm before moving to larger models where integrative complexity increases. However, this would be interesting for larger data sets or data sets with larger models. With the decision to focus on triads, and with the above cut-off criterion on the number of triads, the algorithm (see Technical Annex) selects them in an optimal way: it chooses those that jointly achieve the maximum possible coverage of models. Although this paper is already an advancement of the analysis of dyad archetypes, future research can extend the analysis for larger configurations. The algorithm also works for those. This would also allow for stronger theorizing in future research. In our qualitative analysis, due to space limits, we were not able to fully explore all cases where frequent triads appear. In many models, the triads occur together with further variables.

In addition, there are issues related to how we applied the SES framework. First, we did not employ the multi-tiered structure of the SES framework, which contains variables on different levels of abstraction. To enable comparisons, it became necessary to employ relatively coarse measures of the presence/absence of variables, neglecting differences in measurement and strength across studies. It could prove interesting to employ more detailed coding of variables, their different relations (causality with different directions, mediating variables, correlations, and so on) and whether they positively affect outcomes. This would yet require a more homogenous sample of cases. There are additional barriers and challenges for doing this, including how to interpret causality in primarily qualitative data and texts from other authors, even when published. More importantly, extending this research would require a larger corpus that explicitly codes variable interactions, for example, for a more detailed analysis of causal relationships. Consider triads together with an outcome. Combinatorially, there are 64 distinct ways to establish directed links between two variables within a triad or between one of them and an outcome. Consequently, our eight archetypes could, in principle, be refined into as many as 512 more granular "sub-archetypes" However, since archetype analysis requires a repeated occurrence, our current sample size remains a limiting factor. That said, we are approaching a meaningful threshold. As more studies utilizing the SES framework emerge, such a refined analysis may soon become feasible. Our present findings provide a strong foundation for such an extension, as the eight archetypes can serve as a structured starting point. If certain triads consistently appear in specific directional configurations, this would not invalidate our results but rather enhance them. Each of the eight archetypes could be systematically leveraged in a focused meta-analysis to cumulate more nuanced insights into sustainability outcomes.

5 | Conclusions

This paper started from the fact that environmental governance case studies increasingly use the SES framework. Like other frameworks used to study SES (e.g., Anderies et al. 2004; Binder et al. 2013; Geels 2004; Hagedorn et al. 2019), it helps to facilitate place-based SES analysis while providing an opportunity for comparing the commonly used variables across the studies that use it. The challenge is more on how to organize this process in order to not be overwhelmed by a huge amount of diverse data across quite particular case-level contexts and theories. Developing novel synthesis methodologies is crucial for making progress on this problem. Thus, we adopted an archetype approach combined with a model-centered meta-analysis to identify salient triads of SES variables.

With the novel procedure, we find eight archetypes, each characterized by a triad of three SES variables, which occur in surprising configurations (in terms of the lift metric). All triads individually occur frequently and jointly maximize the coverage of the coded models from the corpus. We consider the eight triads as archetypes because we can demonstrate that they are theoretically reasonable and can be meaningfully contextualized when going back to the case studies. The eight archetypes are: shared operational agency; property and accountability; leadership structure; community self-efficacy; informal collective decisions; small households in remote, inaccessible places; formal investment conditions; resource quality and allocation. Based on these findings, we show how combinations of two or three archetypes can be used like building-blocks. Building-blocks can be independent from each other or connected by variables in the intersection of different archetypes. These can lead to more complex configurations which might be linear, re-enforcing or balancing. Thus, by using archetype analysis, we found configurations of SES variables in identifiable patterns of three, which are present across cases and contexts. This is a useful demonstration of how methodological innovation can make needed progress towards synthesizing the vast amount of environmental governance literature that uses an SES framing. This can be the starting point for a more thorough theorizing about the mechanisms underlying those configurations, can help for future case study research, to obtain policy implications, and for systematic knowledge cumulation.

While many researchers have worked with the SES framework and found evidence in local contexts, the task of comparing across cases, developing theories, which hold in different contexts, and cumulating existing knowledge remains of utmost importance. All of the place-based SES research we now have—when considered as a whole body of knowledge—will very likely have identifiable elements and patterns in it; we just need to identify them in systematic ways. A core justification for doing case study research is to contribute new empirical material to support theory at some broader level. The field has arguably lost sight of this goal while justifying the need to further contextualize research to local contexts. As observed in the other branches of environmental governance research (Khmara 2024; Newig and Rose 2025; Wood et al. 2025), doing so has increased research fragmentation, impairing the field's potential for meta-analyses and cross-case knowledge cumulation. Novel methods for knowledge cumulation can resolve some of these pending puzzles, for example, linked to specific variables (e.g., group size and heterogeneity), or to variables for policy intervention. It is clear that synthesizing a body of empirical literature requires some basic level of data comparability, as offered by common vocabularies of attributes (Eisenack et al. 2021), or frameworks—which aim to "identify,

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categorize, and organize those factors deemed most relevant to understanding some phenomenon" (McGinnis 2011). Good frameworks are yet not straightforward. First, general variables (e.g., number of actors) can be interpreted or operationalized differently among theories and cases (e.g., actors being people, firms or countries) (Partelow et al. 2024). Hence, we sometimes need to transform more granular variables to more abstract ones in order to enable comparison among data from different studies. This is one reason why the SES framework has a multi-tiered set of variables. Second, our paper shows that we additionally need frameworks which can help facilitate the conceptualization and measurement of variable interactions or mechanisms in order to pursue further methodological and conceptual advances. It is not sufficient to just classify the presence of abstracted variables, or to link single independent variables to single outcomes. We hope the presented archetype analysis serves as a possible stepping stone in this regard. In light of the increased rate of publications, finding patterns across research outcomes can bring scientific progress as well as applicability or solutions for collective action in various contexts.

Acknowledgements

Dr. Elke Kellner acknowledges financial support from the Horizon 2020 MSCA-IF-2020 (Grant no. 101027966). We thank the participants of 7th International Workshop on Archetype Analysis in Sustainability Research for their constructive feedback (www.archetype-analysis.net). Open Access funding enabled and organized by Projekt DEAL.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data used has previously been published by Villamayor-Tomas, Sergio, Christoph Oberlack, Graham Epstein, Stefan Partelow, Matteo Roggero, Elke Kellner, Maurice Tschopp, and Michael Cox. 2020. "Using Case Study Data to Understand SES Interactions: A Model-Centered Meta-Analysis of SES Framework Applications." Current Opinion in Environmental Sustainability 44: 48-57. https://doi.org/10.1016/j.cosust.2020.05.002. The R code for the optimal selection of configurations is provided as the function 'atsel' on https://github.com/ArchetypeAnalysis/Archetype-Identification.

Endnotes

[1] Instead of Archetype 8, optimal coverage can also be achieved with one of the following triads:

Triad	Frequency	Lift
Leadership (A5)-Resource dependence (A8)-Collective choice rules (GS6)	10	8.61
Investment activities (I5)-Government organizations (GS1)-Non-gov. organizations (GS2)	5	20.0
Investment activities (I5)-Leadership (A5)-Resource dependence (A8)	7	6.03

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Appendix A

The SES Framework

See Table A1 for the first and second tier variables of the social-ecological systems (SES) framework (McGinnis and Ostrom 2014).

Coding Procedure and Archetype Analysis

All publications contain case studies on natural resource use (e.g., fisheries, forests, land, water). The corpus was identified through a systematic literature review and coded elsewhere (Villamayor-Tomas et al. 2020). Selection was done in 2019, with no other time interval limitations. Only studies that include primary data and provide some explanatory results were retained.

Coding followed a model-centered meta-analysis approach (Rudel 2008), common in sustainability studies (e.g., Hoffmann and Villamayor-Tomas 2023; Oberlack 2017; Oberlack and Eisenack 2018). The first coding step identified parts of the text with statements containing causal explanations on the case studies, as stated by the authors. Each such statement is called a "model". Papers can contain one or multiple cases,

TABLE A1 | First and second tier variables of the SES framework.

Social, Economic, and Political Settings (S)
S1-Economic development. S2-Demographic trends. S3-Political stability.
S4-Other governance systems. S5-Markets. S6-Media organizations. S7-Technology.

Resource Systems (RS)	Governance Systems (GS)
RS1-Sector (e.g., water, forests, pasture)	GS1-Government organizations
RS2-Clarity of system boundaries	GS2-Non-governmental organizations
RS3-Size of resource system	GS3-Network structure
RS4-Human-constructed facilities	GS4-Property-rights systems
RS5-Productivity of system	GS5-Operational rules
RS6-Equilibrium properties	GS6-Collective choice rules
RS7-Predictability of system dynamics	GS7-Constitutional rules
RS8-Storage characteristics	GS8-Monitoring and sanctioning
RS9-Location	
Resource Units (RU)	**Actors (A)**
RU1-Resource unit mobility	A1-Number of relevant actors
RU2-Growth or replacement rate	A2-Socioeconomic attributes
RU3-Interaction among resource units	A3-History or past experiences
RU4-Economic value	A4-Location
RU5-Number of units	A5-Leadership/entrepreneurship
RU6-Distinctive characteristics	A6-Norms (trust-reciprocity)/social capital
RU7-Spatial and temporal distribution	A7-Knowledge of SES/mental models
	A8-Importance of resource (dependence)
	A9-Technologies available
Interactions (I)	**Outcomes (O)**
I1-Harvesting	O1-Social performance measures
I2-Information sharing	O2-Ecological performance measures
I3-Deliberation processes	O3-Externalities to other SESs
I4-Conflicts	
I5-Investment activities	
I6-Lobbying activities	
I7-Self-organizing activities	
I8-Networking activities	
I9-Monitoring activities	
I10-Evaluative activities	

Related Ecosystems (ECO)
ECO1-climate patterns ECO2-Pollution patterns ECO3-Flows into and out of SES

TABLE A2 | Most frequency of variables (share of all 71 models).

Variable	(%)	Variable	(%)	Variable	(%)	Variable	(%)
A6	39.4	I7	25.4	GS6	19.7	I8	14.1
GS5	39.4	A7	25.4	GS8	19.7	GS1	14.1
A5	31.0	A1	21.1	GS3	18.3	RS3	14.1
GS4	29.6	I1	19.7	A2	16.9	A3	12.7
A8	26.8	I5	19.7	RS4	16.9	GS2	12.7

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and each case one or more models (up to 14 models in the used data), which led to 125 models in total. The models are the unit of analysis of our present study.

Since the analysis is intended to leverage the SES framework, models were coded with the framework's second-tier variables (McGinnis and Ostrom 2014), referring to resource units, the resource system, actors, governance systems, interactions, and socio-economic-political settings (see Table A1 Appendix A (The SES framework)). We used a paired coding process to improve inter-coder reliability. Each paper was coded by two people independently, then checked for consistency. In the case of a discrepancy, a third person (project lead) examined the data and mediated. The third person ensured the coding processes across all the paired groups were consistent in their processes and interpretation.

The combination of quantitative and qualitative analyses follows standards of archetype analysis (Eisenack et al. 2021). The approach, which is compatible with different data-analysis methods, aims to strike a balance between treating every case as fundamentally different and overgeneralizing among all cases. Archetype analysis is helpful for doing this because it produces a suite of multiple archetypes, only intended to rationalize a subset of models. Yet, all archetypes taken together shall cover a large share of the models (see Levers et al. 2018; Neudert et al. 2019; Pedde et al. 2019; Rocha et al. 2020; Roggero et al. 2025; Harmáčková et al. 2025, for examples of other archetype analyses).

Formal Concept Analysis (FCA)

Formal concept analysis, as developed by Ganter et al. (2005a) is now a commonly used method to extract archetypes from a case data set (e.g., Gotgelf et al. 2020; Harmáčková et al. 2025; Oberlack and Eisenack 2018; Tan and Wang 2025). This computational method classifies data based on set theory and mathematical lattice theory. In its simplest form, the input to an FCA is a table, with models in rows (called objects in FCA jargon) and variables in columns (called attributes in FCA). The table contains binary entries which indicate whether a variable is present in a case. This could also be extended to code the polarity of the relations between variables, but this is delegated to future work. With this data, the algorithm computes all possible classifications of the models by the variables used.

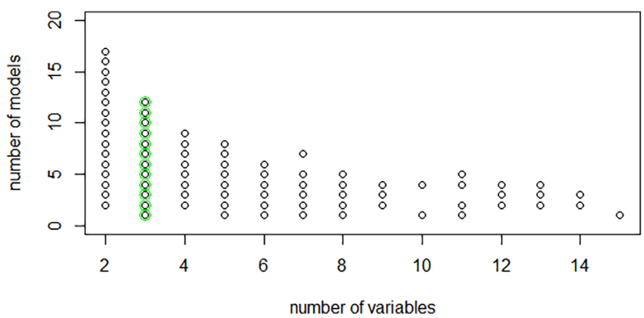

FIGURE A1 | Scatter plot of number of variables and models in concepts (concepts with less than 2 or more than 15 variables omitted).

So far, FCA might look similar to qualitative comparative analysis (QCA; e.g., Schneider and Wagemann 2012). There are, however, some differences, which we think, make FCA more helpful. For instance, FCA does not require choosing one variable as an outcome. While this might be a drawback for other studies, it is an advantage here because we aim at classifying models already substantiated by the reviewed papers, and not at explaining another single outcome. FCA can also cope with very many variables, while it is common practice in QCA to focus on a small set of conditions (e.g., to avoid logical remainders). Also note that our study does not require a fuzzy set approach (which is available for both FCA and QCA), as our primary data is binary.

FCA uses the data to determine what is called concepts. Each concept is described by its extent and its intent. Its extent is a set of models that are covered by the concept, and its intent is a set of variables. The challenge when determining the concepts is that extent and intent need to fit to each other: The extent of a concept needs to contain exactly all models that use at least all its intent's variables (but not more models). For instance, a concept might contain all models that speak about both social norms (A6) and property-rights systems (GS4), and possibly about more. In turn, the intent needs to contain all variables that are common to all models in its extent. So, if all models that speak about A6 and GS4 have a further shared variable, this feature should also be part of the concept's intent.

Algorithms to compute all concepts from large data sets are available for different platforms (e.g., Lopez Rodriguez et al. 2020). It is important to note that those concepts can be quite different in terms of their extents' and intents' size. With the present paper's focus on triads, we only consider concepts with an intent of exactly three variables. But this does not imply that we ignore models which are coded by four or more variables. Such more complicated models can still contain triads which qualify as a concept (actually, our results show that many models contain multiple such triads).

Descriptive Results on the FCA and the Triads

The basic data has already been analyzed by Villamayor-Tomas et al. (2020). Here, we provide some summary statistics. The 71 model

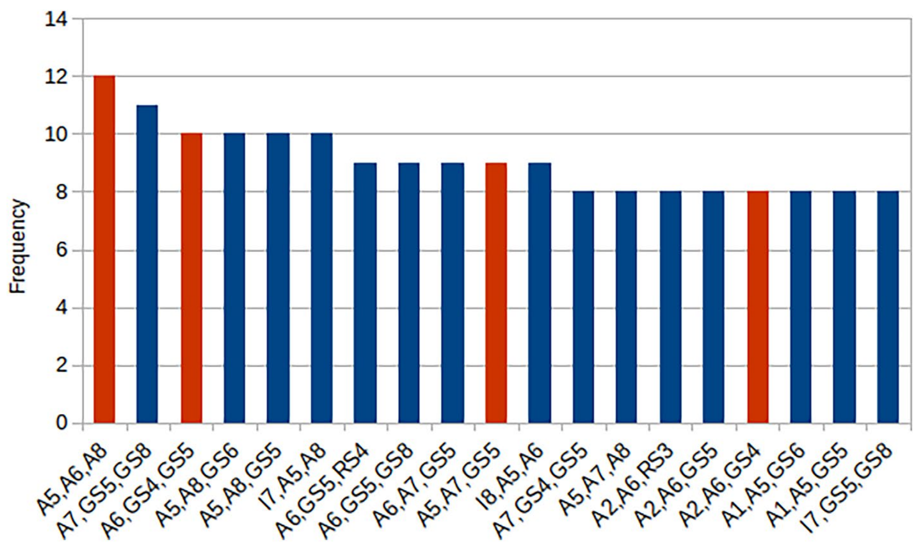

FIGURE A2 | Most frequent triads.

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TABLE A3 | Models in multiple concepts and triads.

N	Number of models being in N concepts	Number of models being in N triads	N	Number of models being in N concepts	Number of models being in N triads
1	.	8	10–14	4	6
2	16	1	15–19	3	5
3	2	6	20–29	6	1
4	12	1	30–39	5	1
5	.	1	40–49	2	3
6	.	3	50–59	2	.
7	4	5	60–69	4	.
8	4	1	70–79	1	.
9	.	.	> 80	6	.

TABLE A4 | Papers with models combining archetypes.

Number according to Figure 1	Combination of archetypes	Papers
1	Archetype 1: Shared operational agency Archetype 4: Community self-efficacy	Begossi et al. (2012) Carrillo et al. (2019) Partelow et al. (2018)
2	Archetype 1: Shared operational agency Archetype 3: Leadership structure	Begossi et al. (2012) Epstein et al. (2014) Partelow and Boda (2015) Partelow et al. (2018)
3	Archetype 2: Property and accountability Archetype 5: Informal collective decision Archetype 7: Formal investment conditions	Bauwens et al. (2016) Begossi et al. (2012)
4	Archetype 2: Property and accountability Archetype 4: Community self-efficacy Archetype 5: Informal collective decisions	Begossi et al. (2012) Carrillo et al. 2019 Partelow et al. (2018)

variables appear in 55 distinct configurations. The 20 most frequent variables occur as follows (see Table A2).

Of the 71 models, 30 are coded with just one or two variables. So, they can never be part of a triad. Yet, models with two variables have already been analyzed by Partelow et al. (2024). Overall, 58% of the models are coded with three or more variables. Several models have more variables (31 models with at least 5 variables, 14 with 10 variables, 7 with 15, and 5 models were coded with more than 20 variables).

The FCA computes 345 concepts. We can plot the number of variables in each concept against its number of models (see Figure A1). With our focus on triads, we only further analyze the 69 concepts corresponding to the highlighted column.

The 19 most frequent triads are as follows (Figure A2). Highlighted in red are those which were ultimately identified as archetypes (archetype 1, 2, 4, 5). The other four archetypes appear less frequently (archetype 3, 6, 7, 8).

One can also count how frequently models appear in multiple concepts or triads (see Table A3). Due to the large number of concepts it is quite common that they appear several times.

Papers With Archetypes as Building-Blocks

The full list of papers where the combinations of archetypes in Section 3.2 occur is provided in Table A4.

Technical Annex on the Optimal Selection of Configurations

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