Construction of archetypes as a formal method to analyze social-ecological systems

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Abstract

The context-dependence of social-ecological dynamics makes it extremely difficult to draw general conclusions about determinants of effective environmental governance. Generic design factors can be too abstract to be applied to concrete environmental problems because every case is different. However, it also appears that many cases of (un)successful governance can be compared, but the transfer of experience between cases requires an adequate notion of similarity. We present archetypes as a method for this task, which can be expanded to a formal as well as to a qualitative approach.

Archetypes are building blocks of society-nature interaction that reappear in multiple case studies, if they are sufficiently abstracted. The underlying hypothesis is that good practices can be transferred if archetypes are shared. This method was used for the syndrome approach, from which examples are given, and where building blocks are simple formal models that can be refined to the peculiarities of each case.

The approach has the advantage of being a bridge concept between case-oriented qualitative and variable-oriented methods. Currently, we have the impression that research on the institutional dimensions of global environmental change does not take full advantage of the latter. Complementary with non-formal methods, they could strongly contribute to future research.

Introduction

Understanding the local and regional dynamics of social-ecological systems is essential for transition processes towards sustainability. Land-use changes, vulnerabilities, mitigation and adaptation to climate change, natural resource management, to name just a few, take place on the local scale and are influenced by particular socio-economic and bio-physical conditions. At the same time, local decisions aggregate to global consequences, such that regional dynamics cannot be thoroughly analyzed without considering interactions between different spatial, temporal and institutional scales. Nevertheless, even if based on international agreements, decisions finally have to be implemented on the local scale.

Local citizens and decision-makers are nowadays confronted with broad information on global environmental change, which is nevertheless difficult to comprehend, prioritize and process with limited resources or even capabilities. If stakeholders have a basic problem awareness about an opportunity or a threat, they often ask whether they should react at all, and if so, what to do. However, blueprint solutions are not available in most cases. What is probably needed is a "rapid vulnerability assessment" to clarify the need for action and develop pragmatic measures taking account for ubiquitous uncertainties. The question is how science can contribute to such efforts.

This is complicated by the context-dependence of social-ecological dynamics, making it difficult to draw *general* conclusions about determinants of effective environmental governance. This view is established in the literature (e.g. Warren, 2002; Schachhuber 2004), also on the level of pure ecological theory (e.g. Shrader-Frechette, 1993). It is supported if institutional design factors meant to be generic can only reach this objective if they are very abstract (Schachhuber, 2004). This requires considerable refinement when they are applied to concrete environmental problems, raising the question whether they are of practical use beyond theory. On the other hand there are also promising results, which do not represent a grand theory, but a collection of generic success factors (e.g. Ostrom, 1994). It thus appears that many cases of (un)successful governance can be compared. To be useful for establishing best practices and transferring experience, such a comparison should not be too coarse-grained. This requires a notion of similarity on an appropriate level of abstraction.

A related challenge is the integration of knowledge from quantitative modelling with qualitative case study research. Quantitative analyses are often criticized for overgeneralization since they disregard context by hiding processes behind data and variables. In contrast, qualitative studies are questioned for being vague and not transferable to other cases. This asserts a dichotomy between quantitative (statistical, mathematical, computational) and qualitative (interpretative, dialectic, hermeneutic) methods. Typically, quantitative work is identified with nomothetic, and qualitative with idiographic research (cf. Windelband 1894). An underlying theme of this paper is thus the apparent dichotomy between qualitative and quantitative approaches to science.

Since a considerable part of the subtleties of global environmental change lies in the entangled structure of the problems, the involvement of experts from various backgrounds and (scientific) cultures is necessary. The different facets of the challenge, addressed in different disciplines are additionally complicated by various uncertainties and complexities. It is an open debate whether current forms of science are appropriate for such kind of hybrid problems, or are even at their root (Latour, 1993). Mental frames rooted in disciplinary practices, languages and communication patterns across different disciplines have to be bridged (e.g. Klein, 1990). Providing an integrated overview together with in-depth knowledge is beyond the capacities of a single scientist. At the same time an integrated perspective is essential to adequately understand global environmental change.

We present archetype analysis as one approach to these challenges. Here, patterns on the regional level are considered with the aim to get a global overview of trends of society-nature interactions and their interconnectedness. At first the concept and its basic objectives are introduced. Then, some examples are given (Syndromes of Global Change, Global Environmental Outlook, Adaptation in the Baltic Sea), and the scope and current challenges of the approach are discussed.

Basic Concepts

Archetypes are representative patterns of the interaction between society and nature bringing about global environmental change and/or being a response to such changes. They illustrate basic underlying processes and are made to draw connections between regions and to assist decision-makers recognizing their particular situation within a broad context. They are building blocks of social-ecological interaction that reappear in multiple case studies, meaning that they can be found at different places around the world because these places share certain conditions. Starting from the premise that every place is particular, speaking of reappearing patterns requires that they are sufficiently abstracted to cover relevant properties of multiple specific cases. This abstraction should be general enough to be potentially found in more than one case, but *not* so abstract it they explains *every* case (which would make it meaningless). One criterion for the appropriate degree of generalization is the underlying assumption that successful institutional arrangements can be transferred between cases if they share archetypes.

It goes without saying that transferable policies remain general to a considerable degree, being the price of the generalized nature of the patterns. The objective of an archetype analysis can only be to obtain a pragmatic degree of fit between abstract problem description and generic policy options, which aims at being as concrete as possible without losing overview. This approach is fundamentally different from deriving a grand theory that comprises all cases, and from idiographic descriptions of single cases that are not compared.

We use the term “archetype” starting from a vague sense that is similar to the use of the word “pattern” (which we will use synonymously), although both terms are more crisply defined in different scientific domains (e.g. Kelso, 1997). Its meaning refers to complex objects of cognition, for example as “ideas of modes and relations” (Locke, 1690), but also to the common notion of a “primordial image, character, or pattern of circumstances that recurs throughout literature and thought consistently enough to be considered universal” (Encyclopædia Britannica, 2006), which is influenced by the terminology of Jung (1954). Alternatively, we can use the term to denote a defining example for a certain type, and subsume different instances by similarity to this example. In this sense, the notion of an archetype resembles that of an ideal type (Weber, 1922). Then, reappearance of archetypes is not defined by being a member of the same abstract equivalence class of cases as indicated above, but by family resemblance (Wittgenstein, 1953) to a paradigmatic case.

We describe archetypes as building blocks, because it is not required that every case can completely be explained by a single archetype. That does not mean that single cases can be explained by different alternative archetypes, but that they cover social-ecological systems only partially. While one case can be considered as a functional unit of society-nature interactions and relations, each archetype covers only a selective part of these relations. For a comprehensive picture of a single case it is in general necessary to combine several archetypes. The above generalization criterion, which refers to shared archetypes, only makes sense in this context. When two cases can *partially* be described by the same pattern, this does not imply that they appear *completely* identical from the abstracted perspective.

Multiple archetypes are joined to a suite that represents a set of building blocks, which covers a variety of cases while taking account for relevant case-specific particularities. Such a suite allows for a typology of cases. It is not complete in the sense that every case can be subsumed under one type, but a partial classification, meaning that every case can be associated with one or more archetypes. If such a suite of archetypes is comprehensively developed, this allows for

1. a suite of global maps which indicates the places where each pattern occurs,
2. for each case an archetypical explanation of local problems and opportunities,
3. for each case a set of relevant best practice examples or generic policy options.

In principal, archetypes can be described in different ways, from formal to non-formal, by narratives or quantitatively, with a descriptive or prescriptive focus, and so on – depending on the objectives of the analysis. We regard this openness as essential for a successful inter- or transdisciplinary application of the approach. The style and language of description (and the analysis methods behind that) needs common ground for all involved scientists (and potential stakeholders). For sake of clarification, we introduce the following semi-formal structure to describe archetypes. It should only serve as a starting point for other formulations. The construction of archetypes begins with a social process where a team of experts and/or stakeholders identifies relevant variables and relations comprising bio-physical and socio-political dimensions of a set of case studies. The definitions of variables are *not* presupposed to be shared by *all* cases. Finally, an archetype is constituted by a functional unit of variables and relations between them.

Variables are understood in a broad sense as being symbolic representations which can be associated with changing or differing values, where values are not restricted to numbers (as quantitative indicators), but can be any attribute or other qualitative property (as adjectives or types of actors). These (general) values may change with time or between different cases. They are supplied with a semantic such that they have an intended meaning. However, this semantic is abstract, meaning that variables like "natural resources" can be specified as forests in one case and as soil quality in another. This generalization is a further device for making archetypes generic without blurring particularities. The best choice for an appropriate degree of generalization of variables depends on the objective of the study, but also on the amount and character of available information and the techniques needed to process this data. This emphasizes again that archetype analysis is principle open for formal and non-formal methods.

Relations hypothesize influences between variables. There can be various types of relations depending on the scope of the analysis and the chosen methods. They can be causal, functional, quantitative, logical, statistical, mechanistic, defining, attenuating, dampening, excluding etc. They are the main device to describe processes which bring about problematic or desireable changes. There may be multiple relations forming causal chains of self-enforcing feedback loops, but also conceptual pre-conditions for relevant phenomena to occur. They can link external factors (e.g. from the global scale) to singular cases, and draw the connection between policy options and their potential effects. We think that the general and flexible term of a relation is well suited for (quantitative) modelling but also for qualitative data analysis. Thus, adequate methods can be formal as well as interpretative, and empirical as well as conceptual. An alternative to relations could be a set of typical (qualitative or quantitative) timelines of the variables, which only need to be "fragmentary scenarios", just telling the narrative of a subset of the variables. For a complete characterization, a large ensemble of such fragmentary scenarios may be necessary.

Variables as well as relations need to be grounded in theory and observation. Their definitions need to fit to the whole suite of archetypes and are not independently from each other. Changing the specification of a variable during construction of archetypes may require modifications of the set of relations, and hypothesizing new relations may require changes in variable specification. It is a feature of a well-developed suite of archetypes, that variables and relations are consistently formulated.

Examples

The basic ingredients of archetype analysis are not totally new. The motivation to distil general knowledge by comparative analyzes is at least as old as modern science. The particular feature of archetype analysis is to understand the dynamics of social-ecological systems in a way as general as possible, but fine-grained enough to account for local particularities.

Ragin (1987) propagates Boolean analysis of qualitative data and selection of abstract variables for political science and history. His qualitative case study analysis (QCA) derives a general logical formula that explains all dependent variables of a selected set of cases from the Boolean values of the independent variables. An example is a study to explain regime effectiveness from non-material reward and punishment (Stokke, 2004). If this is possible at all for a larger sample, the resulting formula can become quite complex. Although QCA aims at deriving a formula as simple as possible, it can equivalently transformed to so called disjunctive normal form, meaning that it is expressed like "the property described by the dependent variable holds for all cases where ... or ... or ....", where a list of alternative conditions is linked by logical "or". This resembles that not a single archetype but a whole suite may be necessary to classify the cases, resulting from the target to avoid over-generalization.

Also in the domain of systems dynamics, paradigmatic models of management problems were developed under the term of archetypes (e.g. Wolstenholme, 2003). These models are formulated using causal-loop diagrams and aim at deriving generic solutions. One difference to the definitions made here is that they are purely syntactical, meaning that the variables have no intended interpretation and that the scope of application is expected to be very broad. These systems archetypes lead some authors to interesting distinctions of different ways of conceiving generic structure (Lane and Smart 1996).

Geist and Lambin (2004) and Lambin et al. (2003) used an approach similar to archetype analysis for extensive meta-studies to explain desertification and tropical deforestation. This work is also motivated by preserving descriptive richness of local case studies while contributing to a general understanding of the issue, including interactions, causes and feedbacks, trying to find a middle way between quantitative and qualitative approaches. Their comparative method focuses on configurations of causally relevant explanations that are similar in their outcome.

The patterns they derive are based on core variables describing climatic, economic, institutional and other factors that reappear in multiple studies. It is assessed which of them explain degradation, distilling four main so-called clusters of proximate causes: agricultural activities, infrastructure extension, wood extraction and increased aridity. However, for most cases more than one proximate cause is relevant, suggesting that the combination of several causes is at the root of the problem. Interweaving them creates a field of combined patterns, which are evaluated for frequency in the selected sample of case studies. Since not every case is explained by the same combination of patterns, we can qualify them as reappearing building blocks describing shared conditions of a sub-set of cases, making up a whole suite. The above clusters also illustrate the attained degree of abstraction. Since the major focus on the study is explanation and not prescription, the generality is mainly driven by the need to classify all cases of the sample with a manageable number of proximate causes.

Proximate causes are not meant to explain problems unrelated to land degradation in the case study areas, such that they are only partially covered – being sufficient for an archetype analysis. On further type of causation used to describe degradation patterns are driving forces. While proximate causes are human activities at the local level, the latter refers to fundamental social and bio-physical processes. Like the former, it was also possible to grouped them into broad clusters. Based on the careful identification of variables and causal relations, partially forming enforcing feedback loops, the description of the building blocks closely resembles the formal style outlined in the last section. Internal and external factors are distinguished and variables have an abstract meaning, allowing for a tailored individualisation for particular cases (e.g. wood extraction also covers related activities).

The Syndrome Approach

A seminal example for an archetype analysis is the syndrome approach proposed by German Advisory Council on Global Change (WBGU, 1993; Schellnhuber et al., 1997). The approach was originally inspired by the medical sciences, where typical combinations of pertinent co-factors constitute syndromes. They were identified as clusters of dynamic variables like “urbanization”, “increasing indebtedness” or “global warming”, called symptoms. These symptoms are relatively general in nature, allowing for case-specific refinement. For example, variables like “natural resources” can be specified as forests in one region and soil quality in another. These symptoms are related to each other by enforcing or dampening influences, meaning that certain trends of global change have an effect on other trends. All symptoms and their interactions together are seen to represent the complex dynamics of global change. Syndromes are then introduced to disentangle this web of relations by identifying sub-dynamics of closely related trends, such that the overall dynamics can be decomposed by appropriate syndromes. This is a top-down approach where syndromes are not building blocks but analytical units.

Choosing trends as variables makes syndromes dynamic. Variables were selected by the members of the WBGU and a parallel multidisciplinary project and focus on processes that are judged as negative. The resulting list contains about 80 variables most of which are classified by the disciplines where they are traditionally investigated. The broad variety of relations between these variables was clustered to 16 groups, called Syndromes of Global Change (see Tab. 1). Some are being called utilization syndromes, some sink syndrome and others development syndromes.

The syndromes were refined by developing quantitative indicators for their intensity and their disposition (Lüdeke et al., 1999; Kropp et al., 2001; Lüdeke et al., 2004). The former refers to the actual occurrence of syndromes in a specific region, while the latter to the potential that a syndrome may occur if certain exposition factors trigger a problematic development in the future. The indicators where based on qualitative and quantitative data which were integrated by using techniques from fuzzy logic (Zadeh, 1965).

Subsequently, the syndrome concept was further developed, in particular to strengthen the case study related perspective, to investigate the Urban Sprawl Syndrome, the Sahel Syndrome and the Overexploitation Syndrome in more detail (Sietz et al., 2006; Reckien and Lüdeke, 2006; Kropp et al., 2006). The syndromes are formulated on an intermediate functional scale, meaning that they are not meant to be as general as a grand theory would require, but also not as detailed to be only applicable to singular cases (Schellnhuber et al. 2002). This perspective makes them abstract building blocks that can reappear in different cases.

Table 1: List of 16 Syndromes as proposed by the WBGU (1993).

Utilization Syndromes	
Sahel	Overuse of marginal land
Overexploitation	Overexploitation of natural ecosystems
Rural Exodus	Degradation through abandonment of traditional agricultural practices
Dust Bowl	Non-sustainable agro-industrial use of soils and bodies of water
Katanga	Degradation through depletion of non-renewable resources
Mass Tourism	Development and destruction of nature for recreational ends
Scorched Earth	Environmental destruction through war and military action
Development Syndromes	
Aral Sea	Damage of landscapes as a result of large-scale projects
Green Revolution	Degradation through the transfer and introduction of inappropriate farming methods
Asian Tiger	Disregard for environmental standards in the course of rapid economic growth
Favela	Socio-ecological degradation through uncontrolled urban growth
Urban Sprawl	Destruction of landscapes through planned expansion of urban infrastructures
Disaster	Singular anthropogenic environmental disasters with long-term impacts
Sink Syndromes	
Smokestack	Environmental degradation through large-scale diffusion of long-lived substances
Waste Dumping	Environmental degradation through controlled and uncontrolled disposal of waste
Contaminated Land	Local contamination of environmental assets at industrial locations

The methods for describing syndromes were improved using qualitative differential equations (QDEs, Kuipers 1994). All variables and inter-relations of a syndrome are described by an extended causal-loop diagram, where typically a core of basic relations can be identified which is responsible for the main dynamics. Using QDEs, all temporal sequences of trends in the variables that are consistent with the core can be computed (see Petschel-Held et al., 1999; Petschel-Held and Lüdeke, 2001; and Eisenack, 2006a for examples). One interesting feature of this formal method is that is merely uses the causal-loop diagram (cf. Richardson, 1986) as input, such that no quantities or mathematical functions have to be defined. This is not only practicable, but essential for an appropriate formalization of the syndrome concept, which fits to the characterisation by variables and relations outlined in the last section. Theoretically speaking, a causal loop diagram subsumes a broad set of cases, where, for example, a certain attenuating influence may be weaker or stronger. They thus define a functional building block that can be applied to all cases where only the so-called polarity of influences (being dampening or enforcing) fits, but nothing is required for their strengths (Eisenack, 2006; Eisenack et al., 2006c). The price for that generality is that the computation of a QDE doesn't make a prediction, but produces a (large) tree of scenarios. Furthermore, every "storyline" of these scenarios is not described quantitatively but only as a sequence of trends (which may reverse) and thresholds (which may be transgressed).

By working with this method, two ways of defining a pattern of global change are possible: as a network of relations (which may bring about a set of scenarios), or as a set of scenarios (which may be explained by a relational network). In many modelling studies it was observed that relational networks that initially appeared as problematic can also produce positive scenarios under some conditions, making the term "syndrome" inappropriate. It is thus currently proposed to clarify the terminology by calling the relational network an archetype, and denoting solely the problematic scenarios consistent with the archetype as syndromes, while positive scenarios are called paradigms. Based on this distinction, refined research questions about the conditions leading an archetype to syndromes or paradigms can be posed. If successfully answered, this give strong hints for the development of policy options. It appears that the inter-locking of problematic trends is a central category to understand such conditions. If a case comes into a configuration with self-enforcing trend combinations, it can irreversibly "snap" into a syndrome or paradigm (Eisenack and Petschel-Held, 2002; Eisenack, 2006). The analysis concentrates on clusters of mutually stabilizing trends that have the potential to bring about persistent dynamics that are judged as positive or negative according to normative specifications of the study.

Global Environment Outlook

The vulnerability of human-environment systems to environmental and socio-economic change is currently investigated within one chapter of the 4th Global Environment Outlook (UNEP, 2007). The analysis is structured along seven so-called archetypes of vulnerability. Objective of GEO-4 is a comprehensive report about the global state of the environment. This is achieved by combined peer review and participatory processes where governments, scientists, policy experts and other stakeholders contribute to environmental assessment, aimed at bridging the gap between science and policy decision-making (UNEP, 2006). Archetype analysis was used to identify challenges and opportunities of cross-cutting environmental and social processes related to material assets, health, security, social relations, and freedom of choice as components of human well-being. The author team do not take a strict formal variable-oriented approach, but identifies basic problematic processes from literature review. The degree of abstraction in the suite of patterns is determined by coherent technical and policy options to respond to the challenges and opportunities. The target is to provide responses that reduce vulnerabilities while protecting the environment. Organized around such responses, the non-exclusive list of archetypes relates to global commons, contaminated sites, drylands, energy production, Small Island Developing States, technological fixes for water shortage and urbanization in coastal zones.

The archetypes are brought about by environmental and socio-economic changes and conditions that create vulnerabilities. Without going into the detailed definition of these archetypes (which are currently in the final preparation phase), we can indicate that this suite of problem descriptions exhibits the basic properties of archetypes outlined in the last section. It is clear that the “archetypes of vulnerability” refer to reappearing issues, e.g. the atmosphere or deep sea fisheries as global commons. They can be shared by multiple case studies, e.g. (rapid and poorly planned) coastal urbanization in various agglomerations around the world. It is not claimed that the list is exhaustive, which is however not required as discussed above. Finally, they are abstract descriptions to be capable of referring to generic problems. For example, technological fixes for water problems analyzes the consequences of different large-scale options as canalization of rivers, large desalinization plants and dams. It is claimed that they can be subsumed under one archetype since successful responses can be transferred between these sub-types. The description concentrates on dams that are justified as paradigmatic for this archetype.

Each description is supplied with a list of potential responses that may help to reduce vulnerabilities. It is assumed that they can be considered as potentially successful if the basic problem description applies. In this sense, the archetypes are fine-grained enough to assume the possibility of a transfer of options. It appears that this is the basic organizing principle for the degree of generalization chosen in the analysis. The authors imply that defining broader functional categories would reduce the list of these options. For example, it is unlikely that the contaminated sites archetype, dealing with harmful and toxic substances that are likely to pose hazard to human health or the environment, and the dryland archetype, which focuses pressures placed on drylands by growing populations, lifestyle patterns and entitlements to resources, can be approached with the same measures. If they were finer resolved towards single cases, proposed options could probably be more concrete, but would thereby miss the objective to provide a global overview with a manageable number of patterns.

The style of archetype description is mainly narrative. The introductory texts summarizes basic problems, risks and their causes, referring to global and local pressures, bio-physical, societal and historical context (e.g. mistakes in the past), entities and processes involved in typical situations, actors and decision patterns. The importance of the archetypes is underpinned by global (partially quantitative) data, maps, typical examples and typical timelines (quantitative or narrative). Before discussing responses, the current vulnerabilities are assessed against criteria of human well-being.

Although variables and their inter-dependencies are not formally defined, the archetypes advert to such concepts. They hypothesize fundamental cause-effect relations, partially internal feedback loops bringing about vulnerabilities, partially exogenous driving forces. This could make them a starting point for further qualitative and quantitative research.

Adaptation strategies in the Baltic Sea Region

In an on-going project, archetype analysis is guiding investigations of adaptation to climate change from a town and country planning perspective. Focussing on the Baltic Sea Region, "Developing Policies & Adaptation Strategies to Climate Change in the Baltic Sea Region" (ASTRA) assesses regional impacts and raises awareness of ongoing climate change and develops strategies and policies for adaptation (ASTRA, 2006). Stakeholders from municipal and regional planning authorities participate together with a multidisciplinary scientific team. Although the challenges of climate change are similar in this region, the particularities in each participating town or region indicate that there are no simple solutions that are identical for every case. However, there is the need for a synopsis of results to initialize learning processes between the involved stakeholders. Another challenge is the heterogeneity of data (legal planning frameworks, economic structure, actor networks, climatological variables) and the need for jointly analysing sensitivity and adaptive capacity to identify vulnerabilities.

These reasons motivate the use of archetype analysis, at least as a guide to structure collaboration in a trans-disciplinary setting with more than 40 partner organizations. As the project aims at deriving solutions, this will be the guiding principle. Identifying conditions under which certain solutions are promising can be described as archetypes if these conditions reappear in multiple municipalities or regions. The current assessment indicates that the local conditions are very diverse (geographical conditions, national legislation, local institutional arrangements, most important exposure units to potential impacts of climate change, etc.), requiring a sufficient generalization of patterns, and making a suite of archetypes a likely result. Since the project showed that climate change is currently not a priority issue on the municipal level due to the presence of further urgent problems, it is not the target to fully understand the dynamics of the participating rural and urban areas.

Some preliminary archetypes currently emerging are the compensation dilemma, shifting responsibilities and water quality stress. They still have a strong hypothetical status and need to be more crisply defined and validated. The compensation dilemma strives for explaining why in many cases new settlements are built or urban infrastructure is renewed in high risk areas (e.g. due to flooding, sea level rise or exposure to heavy storms). Investors, partially from outside, push planning decisions towards their own favour. Strained municipal budgets or local development plans propagate this process, while investors take the risk because of one or several of the following reasons: (i) they are not aware of the problem, (ii) they operate on short time scales, or (iii) they expect that losses due to natural disasters will (at least partially) be covered by public ad-hoc compensation schemes. The latter expectation is not without reasons having past experience in mind. Municipalities may still be interested in not loosing strong investors after disasters, although compensation (in particular if paid at the local level) may bring public budgets to a precarious state again. Efficient responses seem to be possible by involvement from higher institutional levels, for example by mandatory building and planning codes combined with clear rules for liabilities (e.g. mandatory insurance or complete municipal liability).

Shifting responsibilities is characterized by the following observations. A stakeholder survey made in the project indicates that planning offices are generally aware of climate change but see strong constraints in including this issue into their everyday routines because they perceive citizens' awareness is low. To their opinion this weakens their arguments if adaptation measures are in competition with other public issues. Similar arguments are mentioned by sectoral administration (water bodies, construction offices, rescue services etc.). These different stakeholders also complain about missing coordination between institutions, partially blocked by the other side, which is seen as critical for a cross-cutting issue as climate change. Finally, there is a shift of responsibilities to higher institutional levels, since local constraints for implementing adaptation measures are seen as too strong or resources are missing. It is open, to which degree these actors' perceptions of each other are only subjective. If this is the case, the reasons and potential levers for resolutions have to be identified. A further ingredient of this archetype may be increased problem awareness and urgency for action after extreme events occurred, which can diminish again on short time scales.

Since average precipitation is expected to increase in the Baltic Sea Region, water problems are more related to timing of the hydrological cycle and to water quality. Water quality stress may be induced by salinization of ground water in coastal areas due to sea level rise or by eutrophication due to higher water temperatures and actual or past excessive use of fertilizers. The latter illustrates the connection to not directly climate related drivers. The same is true for water demand that strongly decreased in most cases of the study after the radical changes in eastern Europe during the 90ies. Now there is a trend to sell water utilities to large companies, while at the same time private wells are closed and the water infrastructure often needs to be redeveloped. It is still unclear whether these institutional changes contribute to the adaptive capacity of municipalities to ensure water quality.

However, it is yet open whether the project will come up with concise archetypes and in which style they will be described. Due to the strong involvement of stakeholders from the beginning, and due to the strong awareness raising component of the project, it is difficult to come up with an in-depth archetype analysis within project duration in a domain were established theories are rare. This clarifies that the success of an archetype analysis depends on the substantial matter where it is applied to. Whether this approach is suitable for a field of problems is an empirical question that is answered as an outcome of the investigation. If successful, the results can therefore be expected to be more than simple truisms.

Discussion and Conclusions

Constructing a suite of archetypes is a transdisciplinary challenge. Different disciplinary traditions use different language and differences in the relevance of certain issues are confronted. Political scientists may argue for a finer resolution of institutional arrangements, while climatologists may propose to consider further atmospherical processes. Moreover, the discourse typically shifts between concrete and abstract descriptions. Concrete variables can be subsumed by more general ones, resulting in a whole ontology of concepts. Archetype analysis requires the skilful use of synoptic methods, a respectful attitude of the participants and qualified facilitators. To ensure quality, a detailed documentation of the process and its results is essential.

A successful analysis provides a suite of archetypes that can jointly explain sustainable or unsustainable dynamics of a set of local or regional social-ecological systems on an intermediate level of generality. Ideally, the resolution is adequate to transfer promising institutional arrangements between cases.

However, there are some open issues with the approach. The analysis has a normative content, which is not a basic problem, but requires clarification of underlying value judgements. This can probably made in a more systematic way than up to now. The syndrome concept has been criticized for mixing empirical and normative aspects (Grunwald, 2001), and for being biased towards problematic developments, making it less attractive to push for change (Jaeger, 2001) and leading towards reservations, in particular in developing countries. The new role of paradigms and a stronger focus on policy responses shows a direction of improvement in this respect, although the *systematic* development of management options based on archetype analysis is still in its infancy. A further issue of debate are archetypes that cannot be directly locate in space, e.g. related to resources in the oceans or large-scale distribution of pollutants. In these cases it is difficult to define system boundaries. If we define, for example, the whole atmosphere as a sink for greenhouse gases as unit of analysis, we can no longer speak of *reappearing* patterns. Finally, although an archetype analysis on the local scale can be aggregated to a global picture, and although global processes can appear as explaining factors in local patterns, the challenges of scaling are not completely resolved, for example if intermediate institutional levels as nation states play an important role between local politics and international relations.

On the other hand, our understanding and design of institutions governing environmental conditions can substantially benefit from methods bridging the gap between case-specific and generalized reasoning. Archetypes are between these extremes. The approach has the further advantage that - depending on the needs of the study and the capacities of the involved teams - it can be expanded towards a formal as well as towards a qualitative analysis.

Starting form the assumption that an integrated analysis of social and natural processes is necessary to solve problems of global environmental change, we resolve this dichotomy to open up the field for a diversity of methods. Currently, we have the impression that research on the institutional dimensions of global environmental change does not take full advantage of formal methods yet, although there are promising approaches. Formal techniques have power in making assumptions and definitions explicit and in systematically exploring their consequence by deductive reasoning (e.g. Snidal, 2004). To be specific, by a formal model we mean a representation of selected aspects and relations of a case study, using a formal language that omits context. Operations on the representation obey deductive rules and disregard its semantics. It is assumed that some results of operations can be related back to the case study. This definition is not restricted to statistic, quantitative and deterministic reasoning, opening the view to a broad field of mathematical and computational methods that deal with uncertainties, non-quantitative data or exploration instead of prediction (e.g. qualitative case study analysis (Ragin, 1987), field anomaly relaxation (Rhyne, 1995), cellular automata (e.g. Tobler, 1979), fuzzy sets (Zadeh, 1965), neural networks (e.g. Zell, 1994), qualitative differential equations (Kuipers, 1994; Eisenack, 2006; Eisenack et al., 2006a), viability analysis (Aubin, 1991; Petschel-Held et al., 1999; Eisenack et al. 2006b) and more). Complementary with non-formal methods, they could strongly contribute to future research.

A caricature of bio-physical studies is a variable-oriented, quantitative view about the world, where everything is expressed by general formulas and models. Important tools are mathematical, in particular statistical methods and dynamical systems. A simplistic view on socio-political studies is the production of large texts that can be arbitrarily interpreted and come up with conclusions that are either obvious or highly contested. Methods are qualitative, dialectic or hermeneutic. To our opinion, this contrast confuses two aspects of research on sustainability. (i) There are different types of data: quantitative data (as climate data) can be measured as numbers, while qualitative data (as descriptions of institutional arrangements) is more appropriately described by texts. This justifies the critique of research where one type of data is analyzed with methods made for the other type. (ii) There are different "modes" of inquiry: while nomothetic research aims at grand theories which are as general as possible and to abstract from particularities of objects which are irrelevant in the theories, idiographic research focuses on particular properties of cases which constitute differences to other cases and their interpretation. However, we think that qualitative data does not exclude generalized statements, while also quantitative data can play an important role in case-oriented work. This opens a new view on the analysis of social-ecological systems.

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