

# Institutional architectures for social-ecological systems governance towards sustainability

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## Abstract

Social-ecological systems' dynamics challenge institutions and their functions. For a socio-ecological system to be sustainable, a balanced interdependence of societal and ecological systems is vital. Provided the diversity of social-ecological system contexts, different institutional functions are required for sustaining the balanced interdependence of a social-ecological system. In our paper, we perform a theoretical analysis and mapping of four context images of social-ecological systems that relate to four different institutional functions. Based on our analysis, institutions need to balance, to protect, to respond and to mitigate depending on the context conditions. For communicating context and systemic conditions, knowledge transfer transferred between the different actors and across the multiple administration and spatial levels is a critical principle and four knowledge transfer patterns are presented in accordance to proposed institutional functions. Our analysis implies that institutional architectures of social-ecological systems have to allow institutional multiplicity, self-organized coordination and maintain flexible rigidity of formal institutions in order to address both social-ecological system's and governance complexity and dynamics.

**Keywords:** institutions, social-ecological systems, governance, adaptation.

## 1. Introduction

A balanced interaction between the social and ecological subsystems is a critical factor for the social-ecological system's sustainability. In this paper, we call attention to different functions that are required from institutions in order to sustain a balanced interdependence of the social and ecological subsystems under different systemic and contextual conditions. Institutions are seen as essential means for governing social-ecological systems. Institutional capacity in dealing with SES dynamics is a subject of research (see also Berkes and Folke, 1998; Rammel, Stagl and Wilfing, 2007, p.14). In line with this, Berkes and Folke, (1998, p.354) raised the issue of institutional function when regarding social-ecological systems and more particularly resources management when they point that failures –and collapses- of common pool resources occur not as outcomes of human greed but as outcomes of “institutional failures”. Lebel et.al. (2006) argue that the way institutions are structured also plays an important role in the management of environmental resources and note that “polycentric and multilayered institutions appear to be important to building or enabling the capacity to build resilience”.

When examining the interdependencies of a social-ecological system (SES), ecosystem services flow from the ecosystem to the society, while from the society to the ecosystem there are different flows depending on the context conditions. The dominant paradigms for social-

ecological systems view societies either to harm the ecosystem or to be ignorant of ways to preserve it. Hence, the propositions for SES governance rest in the institutional safeguarding of ecosystem services and community's well-being. We argue that, for a social-ecological system to be sustainable, a balanced interdependence of societal and ecological systems is vital. In line with this, our research question concerns: *What types of institutional architectures are needed for social-ecological systems' sustainability?* We start our analysis by investigating and deducing different functions that institutions need to fulfill for sustaining a balanced SES interdependence. For understanding and realizing the systemic and context conditions, knowledge (and information) concerning these conditions need to be exchanged between the actors of the SES. More specifically, we argue that knowledge about the state of the ecosystem dynamics and about the misfits between SES image and institutional operation (or function specifically) needs to be transferred between the different actors and across the multiple administration and spatial levels. Knowledge transfer therefore, in the form of scientific information and in the form of tacit knowledge from indigenous/local communities has a crucial function for sustaining a balanced SES interdependence and will be also elaborated in accordance with the different institutional functions.

### **1.1 Methodology**

Our analysis unfolds in four steps: First, we examine how interdependencies of the SES change under four different context images. We ground our analysis in governance theories of SES and examples of SES' responses for every image. The system characteristics include the practices of local communities (that vary from malpractices to good practices) and the scale of the ecosystem dynamics (that varies from active to latent ecosystem dynamics). Second, for every context-image, the desirable institutional function is deduced from theories and research findings of SES governance that refer to the specified SES image. Third, a working list of knowledge transfer principles that link to institutional functions are presented. Fourth, the implications of the different institutional functions and knowledge transfer principles for institutional architectures and sustainability are presented. A list of definitions of the terms used in our analysis is provided in the Appendix. An elaborate presentation of the methodology steps unfolds in the following paragraphs.

**Step 1-Drawing SES context images:** In our analysis we will concentrate in two characteristics for describing the context images of SES interdependencies: (a) the social practices that are the practices of indigenous communities (or societal response to the ecosystem) and (b) the state of the ecosystem dynamics. The ecosystem is considered under continuous change hence ecosystem dynamics are always present. However the scale of the ecosystem dynamics varies from active ecosystem dynamics where the ecosystem undergoes drastic changes to latent ecosystem dynamics where the ecosystem experiences changes that comply with the revitalizing cycle of the ecosystem. The ecosystem dynamics however may also exert response of the ecosystem to anthropogenic pressures.

When examining the interdependencies of a SES, ecosystem services flow from the ecosystem to the society, while from the society to the ecosystem there are different flows depending on the context conditions. The state of the ecosystem concerns a systemic condition whereas the SES interdependencies and dynamics constitute the context for the institutions established to sustain SES.

**Step 2-Deducing institutional functions:** It is neither our interest to enlist institutional arrangements to respond to every context image nor to criticize the suggested institutional arrangements found in SES research and governance writings. Our objective is to first review theories and research findings of SES governance that depart from the same context image so as to deduce the suggested institutional function. In our view, there may be found different institutional arrangements set in place so as to exert the specified institutional function. Additionally, we argue that a univocal relationship between institutional arrangements and institutional functions does not exist. For example, establishment of quota systems may be used in fisheries so as to establish protection of the ecosystem as an institutional function in one country (in one context); whereas can be used so as to exert adaptation to SES dynamics in another country (different context).

In line with this, the focus on institutional functions allows for an understanding of the desirable outcome of institutional operation and consequently, may provide a new view on how institutional arrangements are implemented and organized. The understanding of institutional functions and their implications for the institutional architecture in which they are embedded are essential when change or introduction of new institutions is suggested:

“The structure of the rule system is important because it can influence interorganizational relationships. Moreover, when looking at attempts to change rules and rule-ordered relationships, it is important to understand the rules currently in place because they can place important constraints on the adoption of future rules” (Imperial, 1999, p.454)

**Step 3-Linking institutional functions with knowledge transfer principles:** Responding to a quest for operationalization of the institutional functions, we propose institutional principles (following Dietz, Ostrom, and Stern, 2003, p.1910, see Figure 3) for knowledge transfer as complementary to those already proposed by SES governance writings (e.g. adaptive governance, co-management, ecosystem-based management, resilience approach and more). Our focus on knowledge transfer as the main principle is based on the realization of the importance of learning in SES governance. More specifically, we argue that for the SES governance as part of the operation of institutions, knowledge about the state of the ecosystem dynamics and about the misfits between SES image and institutional operation (or function specifically) needs to be transferred between the different actors and across the multiple administration and spatial levels. Knowledge in the form of scientific information and in the form of tacit knowledge from indigenous/local communities has a crucial function for sustaining a balanced SES interdependence.

Three carriers of knowledge on SES dynamics have been specified and need to be considered when drawing knowledge transfer principles (Frantzeskaki, et.al., forthcoming) : (a) the local community –Scott (1998) specifically argues that local community actors are the carriers of system’s memory, and Healey (2006, pp.288-289) argues that actor participation in planning processes is the precondition for social learning -, (b) policy practitioners that hold the multi-disciplinary body of knowledge and can incorporate new scientific insights into management practice (Vreugdenhil et al., 2008), and (c) policy innovators that can be viewed as carriers of emerging dynamics and sensors of system’s change (Huitema and Meijerink, forthcoming). The knowledge transfer as a critical operation needs to be realized between these three carriers and between the carriers and the administrators that are responsible for the

institutional performance and operation. Hence, in our analysis, we will only focus on the different subject (whose knowledge), object (what type of knowledge) and mechanism of knowledge transfer in the form of institutional principles.

## 2. Multiplicity of institutional functions for social-ecological systems governance

Institutions are social constructs that under the scope of social-ecological systems governance are the means to regulate, legitimize and protect the interests along with differentiated functions depending on context conditions. Provided this role of institutions, we will elaborate on four different social-ecological system contexts and deduce four different institutional functions required for safeguarding the system's sustainability. In accordance to the institutional functions, we also propose knowledge transfer principles and a working mechanism for the knowledge transfer between different actors so as to exert the suggested institutional function.

“Any institution that is implemented evokes a reaction from people and ecosystems, which then cocreate a system that may become different from the one that the institution was intended to manage. (...) For any proposed institution, an analysis of the reaction of the SES must be considered and this dynamic must be estimated and predicted, before the ultimate outcome of the proposed institution can be evaluated. This analysis is the heart of adaptive management, and the source of potential panacea traps.” (Brock and Carpenter, 2007, p.15207)

### 2.1 Institutions for protecting SES

**Context Image:** The first context image of SES interdependencies maps the situation in which indigenous communities adopt mal-practices when dealing with the ecosystem (e.g exploitation of a natural depleteable resource, or pollution of the ecosystem), and the ecosystem in response is under pressure due to these anthropogenic dynamics. The above described context image reflects the tragedy of the commons described by Hardin (1968). (Figure 1, Context Image I)

**Institutional function:** For dealing with the anthropogenic harm towards the ecosystem and consequently sustain a balanced SES interdependence, institutions are viewed as the means to *protect* the ecosystem. Risen from this context image, Hardin (1968) suggested that two institutional arrangements can deal with the exploitation of natural resources: centralized institutions and property rights.

The need for protection of the ecosystem from the negative effects of human practices provided the driving force for the development of the ecosystem-based management paradigm (Imperial, 1999; Pretty and Ward, 2001). In its early stages, ecosystem thinkers made a distinction between the ‘management’ and ‘engineering’ of the ecosystem. According to ecosystem thinkers (Costanza et.al., 1997; Pretty and Ward 2001), the ecosystem could not be engineered or controlled; rather information from ecologists on the ‘capricious’ dynamics of the system was necessary for effective non- interventionist management. Ecosystem based management suggests institutions to protect the ecosystem from anthropogenic mal-practices (Imperial, 1999, p.454).

In early ecosystem governance writings, the need for centralized institutional arrangements that secure an effective intervention to the problem of the commons is promoted

(see Hardin). In ecosystem-based management research and in common-pool resources management writings (Ostrom, 1990), the strive for non-hierarchical institutions and community-based institutions is presented.

**Knowledge transfer principle:** In the context that a SES is unsustainable due to unbalanced SES dynamics produced by anthropogenic pressures, we propose that institutional arrangements have to exert protection of the ecosystem. For the protection of ecosystems, institutions need to *enable the transfer of knowledge about means (infrastructure and practices) to protect the ecosystem between the policy practitioners, innovators and scientists to the local community.*

## 2.2 Institutions for mitigating SES

**Context Image:** The second context image of SES interdependencies maps the situation in which indigenous communities adopt mal-practices when dealing with the ecosystem and the ecosystem is under pressure due to extreme immanent dynamics. The above described context image contemplates the collapse of ecosystems as described by Diamond (2004; 2005) and other scholars. In Diamond's (2004; 2005) studies, a well-documented case of collapse is the Easter Island community (Figure 1, Context Image II)

More specifically, there are two approaches that elaborate on the collapse of social-ecological systems: the resilience approach and the vulnerability approach. According to the resilience approach, collapse occurs when the SES cannot accommodate the changes (that means that it is pushed beyond its carrying capacity or exceeds its thresholds) and collapse is followed by a reorganization of the social-ecological system (Anderies, Walker and Kinzig, 2006; Walker and Meyers, 2004). Given the inherent complexity of social-ecological systems, collapse is an extreme but intrinsic behavior of such systems when experiencing severe disturbances (see also Bruck, 2002; Abel, Cumming and Anderies, 2006).

In contrast to the resilience approach, the vulnerability approach states that the social-ecological system is vulnerable to changes and is influenced by change (Metzger, Leemans and Schroter, 2005; Parmesan and Yohe, 2003; Manuel-Navarrete, Gomez and Gallopin, 2007). The conceptualization of collapsing from the vulnerability approach complemented by that of ecological-anthropological studies (discussed by Diamond (2004; 2005)) is adopted in our paper. Collapses of SES include the decay or complete destruction of a SES as a result of synergies between systemic and contextual dynamics.

**Institutional function:** For dealing with the anthropogenic harm towards the ecosystem while the ecosystem exerts extreme dynamics, institutions are viewed as the means to *mitigate* the ecosystem. Starting from this context image, environmental management as a SES governance approach proposes mitigation measures for sustaining a balanced SES interdependence. Technology and consequently, technological means (e.g. affluent treatment technology, dike systems, dams, etc) are at the core of the environmental management especially the end-of-pipe management approach.

**Knowledge transfer principle:** For the mitigation of ecosystems, institutions need to *enable the transfer of knowledge about means (infrastructure and practices) to mitigate the ecosystem between the policy practitioners, innovators and scientists to the local community and to promote the generation of knowledge for better understanding of the SES unbalance.* In this SES

context, institutions need to enable and support the generation of scientific knowledge that is required so as to understand the ecosystem dynamics pattern of extreme change as the starting action and then, transfer the knowledge to policy practitioners for mitigating SES unbalance.

“Institutions may promote scientific understanding or research and development directly (as a sole objective or as one part of a larger regulatory effort) or indirectly by raising the salience of an environmental problem so as the government, private and academic scientists (and their national, local, corporate, or private funders) dedicate more resources to the problem. Better knowledge of the causes of an environmental problem and of technological alternatives can increase the motivation to avert environmental change while descreading the counterailing pressures that inhibit changes to existing behavior patterns.” (Mitchell, 2008, p.96).

### 2.3 Institutions for balancing SES

**Context Image:** The third context image of SES interdependencies maps the situation in which local communities have good practices when dealing with the ecosystem and the ecosystem experiences regular dynamics. When local communities are seen to employ sustainable practices towards the ecosystem resources, the local community and social actors are considered to acquire the memory of the system (Scott, 1998) and acknowledged with tacit knowledge. In this context, the local community steward the ecosystem and is directly responsible for its sustainability (Ostrom, 1990; Carlsson and Berkes, 2005; Kofinas, 2009). (Figure 1, Context Image III).

**Institutional function:** Where local communities steward the ecosystem, institutions need to *balance* the interdependence between society and ecosystem for safeguarding its sustainability. Adaptive co-management researchers have worked on deducing institutional arrangements from empirical cases where ecosystem stewardship was realized and management practices for settling ecosystem stewardship to social-ecological systems (Carlsson and Berkes, 2005; Olsson, Folke and Hahn, 2004; Olsson, Folke and Berkes, 2004; Chapin, Kofinas and Folke, 2009; Folke, Chapin and Olsson, 2009). Adaptive co-management is an approach “based on well-accepted ecological principles and adjusts practices to fit local conditions.” (Kofinas, 2009, p.78) and proposes an active involvement of local communities for sustainable governance of the SES. The importance of local communities and local knowledge for ecosystems’ sustainability is also addressed by social science (Scott, 1998) and policy science scholars (Healey, 2006; Hajer, 2003; Hajer and Wagenaar, 2003).

**Knowledge transfer principle:** What adaptive co-management puts on the foreground is the importance of social learning and of knowledge transfer between all the affected actors (Kofinas, 2009; Galaz et. al., 2008). For ecosystem stewardship, institutions need to *enable the transfer of knowledge about SES dynamics between the local community and policy makers and scientists and to create a “common language” so as to enable transfer of knowledge from local communities to policy practitioners, policy makers and scientists and visa versa*. In this SES context, the local community is conceived as a safeguard of the ecosystem hence utilization of system’s knowledge or tacit knowledge from the local community is a priority for policy makers and scientists. The knowledge exchange and learning process contemplate a triple loop as shown

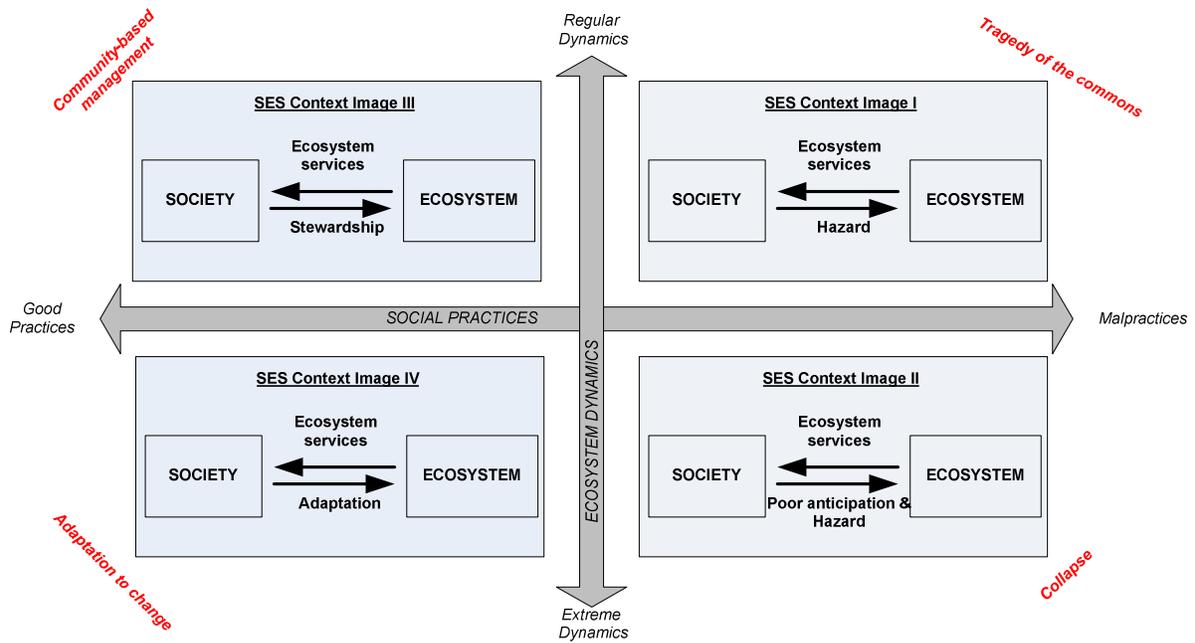
in Folke, Chapin and Olsson, (2009) where learning-by-learning and social learning as the outcome of participatory processes are critical for the SES governance.

## 2.4 Institutions for responding to SES dynamics

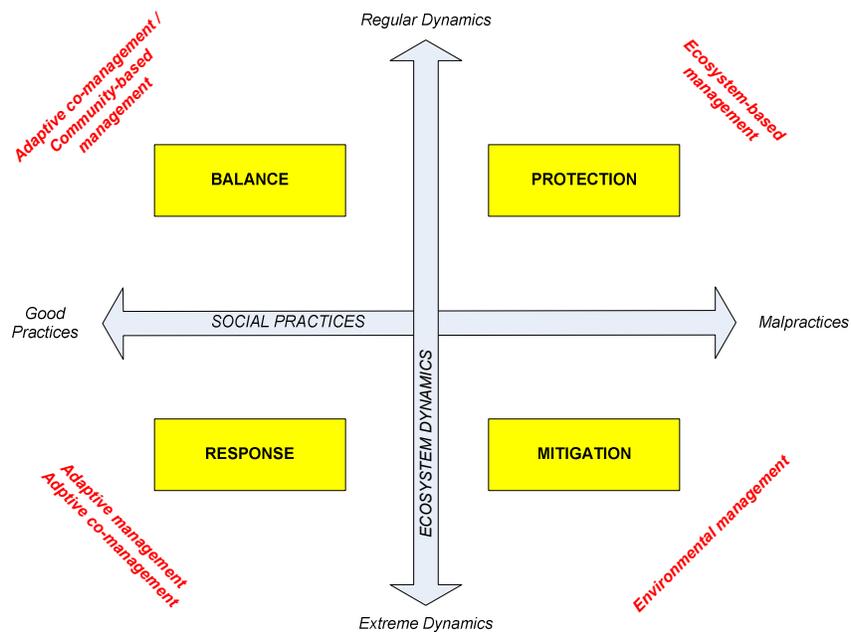
**Context Image:** The fourth context image of SES interdependencies maps the situation in which local communities have good practices when dealing with the ecosystem and the ecosystem experiences extreme dynamics. In this context, local communities (need to) alert their practices continuously so as to adapt to the extreme ecosystem dynamics. An example of extreme ecosystem dynamics is the desertification of semi-arid South European regions (e.g. Spain, Eastern regions of Crete, and Rhodos, Greece). (Figure 1, Context Image IV)

**Institutional function:** Where local communities adapt or strive to adapt to extreme ecosystem dynamics, institutions need to *respond* to the interdependence between society and ecosystem for safeguarding its sustainability. Adaptive co-management as a SES governance approach provides the ground for institutional arrangements that enable adaptation and response to extreme ecosystem dynamics (specifically discussed by Kofinas, 2009). Complementary to adaptive co-management, adaptive management also addresses participative processes and an active role of policy practitioners and scientists in aiding the adaptation to SES dynamics (Hamouda et.al., 2004, p.5032). The adaptive co-management “combines the dynamic learning characteristic of adaptive management with the linkage characteristic of collaborative management” (Galaz et.al., 2008, p.161) that makes it a community-based collaborative version of the adaptive management approach; where the inclusion of all interested and affected actors is at core (Frantzeskaki, et. al., forthcoming).

**Knowledge transfer principle:** Adaptive co-management and adaptive management argue that for adapting to extreme ecosystem dynamics, institutions need to *enable the transfer of knowledge (about SES dynamics) between the policy innovators or leaders (Galaz et al, 2008,p.165), policy makers, scientists and local communities for a successful response towards adaptation to SES dynamics. Policy innovators and/or leading personalities play a crucial role in altering social practices towards successful response and adaptation to SES dynamics.* Leaders or leading personalities are those “who motivate and guide the actors towards pursuing their interests and realize the need for action” (after Olsson et al., 2006). Leading persons are visionaries and knowledgeable people who sense the social need for change and work towards creating the conditions to realize change. Diamond (2005, p.306) also notes the importance of the presence and role of decisive and active leaders “who have the courage to anticipate crises or to act early, who make strong and insightful decisions (...) and can make a huge difference to their societies”.



**Figure 1: Social-Ecological System's Context Images.**



**Figure 2: Proposed Institutional Functions for the different Social-Ecological System's Contexts.**

### 3. Institutional Architectures and Social-Ecological Systems' Sustainability

#### 3.1 Implications of institutional functions for institutional architectures

***Institutional architectures to host functional multiplicity:*** Our analysis of different SES context images shows that institutional functions have to follow systemic and context conditions. Institutional functions and related institutional arrangements vary depending on the SES context images that in return may change over time. The concluding remarks from our mapping of the SES context images briefly include: (a) Institutional multiplicity shows that there are different institutional requirements depending on context conditions and, that there is no a universal institutional arrangement to deal with SES dynamics (b) Institutional multiplicity reflects the complexity of governance of social-ecological systems, and (c) The institutional functions corresponding to SES contexts reflect ideal types of institutional operation when in reality, there are mixtures of institutional functions and institutional arrangements in place and are not immune neither to change nor to opportunism or strategic intervention.

An implicit implication of our analysis concerns the design of institutions and institutional architectures that allow reforms in multiple levels so as to adjust their functions when context changes. We propose institutional arrangements that are flexible and adaptive to context without neglecting the time and costs institutional flexibility requires (see Young, King and Schroeder, 2008, p.29-30). Institutional architectures need to allow co-evolution of institutions with social-ecological systems so as to maintain their effectiveness and improve institutional fitness.

***Institutional Oxymora:*** Another outcome of our analysis concerns the suggestion that formal institutions need to be rigid and reliable for protecting interests, legitimize demands and regulate the system; and at the same time to remain flexible in exerting different institutional functions (protect, mitigate, balance, adapt) relying on SES systemic and context state (context images). Flexibility of institutions as a key requirement is also concluded by adaptive co-management studies for ecosystem stewardship to be enabled (see Kofinas, 2009; Galaz et. al., 2008). A suggestion on *flexible rigidity of institutions* appears to be an oxymoron that responds to the multi-level and multi-scale character of SES governance architecture. More specifically, in a multi-level governance structure, the levels may differ in rigidity and flexibility to change. An example concerns a flexible in change local level of administration, where low-level-administration-rules are easily adjustable and a rigid meso-level or regional level of administration that co-exist in an SES governance structure. The interlinkages and interdependencies of such governance structures form an institutional architecture that has to sustain its aggregated operation and at the same time, orchestrate multiple institutional functions.

Additionally, our analysis suggests that institutional architectures have to coordinate the function of multi-level and multi-scale formal institutions so as to ensure their effectiveness. At the same time, governance of complex systems (such as social-ecological systems) can also follow a self-organized pattern due to emerging governance dynamics and complexity (Kooiman, 2003). Multi-level and multi-issue interaction of actors and institutions yield governance dynamics and complexity and result in institutional nexus that are tolerant to command-and-control interventions. The governance dynamics thus, require an institutional architecture that employs *self-organized coordination* as a means to achieve effectiveness and governance fitness.

In line with these, oxymora like flexible rigid institutions and self-organized coordination of institutional architectures appear as manifestation of the SES governance complexity. We argue that policy makers and administrators should build upon governance oxymora and avoid confronting them either as dilemmas or as dichotomies.

### **3.2 Implications of institutional functions for the sustainability of SES**

*Shifting SES contexts:* Institutions as social constructs (Giddens, 1984; Young et. al., 2008, p.43) are subjects to change following changes in social demands and interests. The mapping of different SES context images reveals the diversity of SES interdependencies and how SES co-constructs both their contexts and the institutions that regulate them. The diversity of SES images however reveals the different context states that a SES can undergo. For instance, in a SES where mal-practices are in place and institutions effectively mitigate them and set in place knowledge transfer, the social practices may change towards good practices with (social) learning. In this way, the operation of institutions along with social mechanisms -such as social learning- can result in a shift of SES context. In this case, institutions are concluded to perform effectively. Institutions however cannot totally control social practices and there are cases that may result in counter-effects when dealing with SES complexity. Such an ineffective operation of institutions is examined by institutional research as part of institutional failures experienced when complex problems are addressed (see Scott, 1998; Eggertson, 2005, pp.41-42). When institutions either fail to operate effectively or do not fit to the SES dynamics – the problem of fit of institutional misfit (Young et. al., 2008; Folke et. al., 2009, p.111), SES’ sustainability is threatened and a shift towards collapse may be realized.

Institutions consequently have to anticipate the complexity of SES and of SES dynamics. Accordingly, administrators need to bear in mind that for SES sustainability, institutions need to adapt to context conditions and allow for shifting in practices that follows the SES context shift<sup>1</sup>.

*Adaptive governance is not an all-time-fit:* Adaptive management and adaptive comanagement as the management approaches linked to adaptive governance paradigm, propose participatory processes and learning by doing for adapting to SES dynamics (see Berkes and Folke, 1998; Olsson, Folke and Berkes, 2004; Frantzeskaki, et. al., 2009). Adaptive governance as the meta-level approach responds to SES context conditions in which ecosystem dynamics are not at extreme and local communities can either contribute with their knowledge to the policy process (community-based management cases) or learn from policy practitioners and scientists how to alter their practices (adaptive co-management cases mainly). In the context where ecosystem dynamics are at extreme values and local communities employ mal-practices, effectiveness in intervention calls for an engineering approach for mitigating severe impacts to the ecosystem; thus environmental management practices are preferred to adaptive governance. Adaptive governance approaches can be adopted in later stages, when mitigation has been achieved, as a means to involve actively social actors and to initiate /enable social learning.

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<sup>1</sup> As also noted in Young (2008, p.135) “no matter how well designed they are, moreover, regimes cannot produce lasting solutions to problems associated with socioecological systems if they lack robustness in the sense of a capacity to withstand day-to-day stresses and resilience or the capacity to adapt to shifting demands without experiencing breakdown or undergoing fundamental change. Problems develop and evolve, sometimes quite rapidly. Institutions that are unable to adjust to changing circumstances are unlikely to produce lasting solutions to the problems they address.”

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## Appendix

Definitions of the terms used in our analysis listed in an alphabetic order.

**Formal Institutions** – systems of rules that guide, regulate, and legitimize actions and activities in a defined area of interest or sector e.g. drinking water or health sectors. Following also Vatn (2009, p.2207) “in practical terms, institutions take the shape of rules – i.e., conventions, norms and legal rules”.

**Governance** – the process of steering towards a desirable outcome or state in the forms of formal processes of decision making (governing processes) and informal processes of societal dynamics (participatory, deliberative and/or emergent processes of societal drive).

**Institutional architecture** – the structure of interlinked formal institutions (including institutions from different sectors) and the system of rules that define and guide their transaction and contact. The above definition builds in the definition of architectures given by Young et. al., 2008, p.42: “the idea of architecture refers to complex linkages among institutions or, more broadly, the elements that make up complex governance systems”. Our definition also agrees with the definition of Biermann et. al., 2009, p.33: “the notion of governance architecture helps to conceptualize the overarching system of public or private institutions, principles, norms, regulations, decision-making procedures and organizations that are valid or active in the issue area. Architecture can thus be described, in other words, as the meta-level of governance.”

**Institutional function** – The aggregate action that a formal institution is established and expected to perform. It can also be seen as the outcome of the operation of institutions.

**Institutional arrangement** – A specific type of formal arrangement (regulated by an administrative organization) such as a quota system, a market, a taxation scheme, a legislation, a law, and more.

**Local community** – The citizens of an region or loci that are part of the social subsystem excluding policy makers, policy practitioners, administrators and scientists.

**Policy administrator or administrator** – The officer employed in a public (state) institutional organization and legally vested with the task to facilitate or monitor the operation of the institutional function for a specific sector (and maybe for a specific issue or connected issues).

**Policy maker** – The expert and/or policy administrator that decides and formulates the policy for a specific issue and for a specific sector (e.g. drinking water policy, flood defense policy).

**Policy practitioner** – The street-level administrators who are assigned to implement the policies (put policies into practice).

**Process** – Flow of events and decision making orderings that are legitimized and organized by and within formal institutions.

## References

- Anderies, J.M., Walker, B.H., and Kinzig, A.P., (2006), Fifteen weddings and a funeral: Case studies and resilience-based management, *Ecology and Society*, Vol.11, No.1 (paper 21) ([www.ecologyandsociety.org/vol11/iss1/art21](http://www.ecologyandsociety.org/vol11/iss1/art21)).
- Berkes, F., and Folke, C. (1998), *Linking social and ecological systems, Management practices and social mechanisms for building resilience*, Cambridge University Press.
- Biermann, F., Betsill, M.M., Gupta, J., Kanie, N., Lebel, L., Liverman, D., Schroeder, H., and Siebenhuner, B., (2009), *Earth System Governance, People, Places and the Planet*, Science and Implementation Plan of the Earth System Governance Project, Earth System Governance Report 1, IHDP Report No.20, Bonn, IHDP: The Earth System Governance Project, 2009.
- Brock, W.A., and Carpenter, S.R., (2007), Panaceas and diversification of environmental policy, *Proceedings of the National Academy of Science of the United States of America*, Vol.104, No.39, pp.15206-211.
- Carlsson, L., and F.Berkes, (2005), Co-management: concepts and methodological implications, *Journal of Environmental Management*, Vol.75, pp.65-76
- Chapin, F.S. III, Kofinas, G.P., and Folke, C., (Eds), (2009), *Principles of ecosystem stewardship, Resilience-based natural resource management in a changing world*, Springer.
- Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Naeem, S., Limburg, K., Paruelo, J., O'Neill, R.V., Raskin, R., Sutton, P., and van den Belt, M., (1997), The value of the world's ecosystem services and natural capital. *Nature*, 387, pp.253–260.
- Diamond, J.M., (2004), *Lessons from environmental collapses of past societies*, Fourth annual John H. Chafee Memorial Lecture on Science and the Environment, January 29, 2004, National Council for Science and the Environment.
- Diamond, J., (2005), *Collapse, How societies choose to fail or survive*, Penguin Books.
- Dietz, T., Ostrom, E., and Stern, P.C., (2003), The struggle to govern the commons, *Science*, Vol.302, pp.1907-1911.
- Eggertsson, T., (2005), *Imperfect institutions, Possibilities and limits of reform*, University of Michigan Press, US.
- Folke, C., Chapin, F.S. III and Olsson, P., (2009), Transformations in ecosystem stewardship, as Chapter 5, pp.103-125, in Chapin, F.S. III, Kofinas, G.P., and Folke, C., (Eds), (2009), *Principles of ecosystem stewardship, Resilience-based natural resource management in a changing world*, Springer.
- Frantzeskaki, N., Slinger, J.H., Vreugdenhil, H., and van Daalen, E., (2009-Forthcoming), *Social-ecological systems governance: From paradigm to management approach*, *Nature and Culture*, Special Issue Reframing Floods, Forthcoming.
- Galaz, V., Olsson, P., Hahn, T., Folke, C., and Svedin, U., (2008), The problem of fit among biophysical systems, environmental and resource regimes, and broader governance systems: Insights and emerging challenges, Chapter 5, pp.147-186, in Young, O.R., King, L.A., and Schroeder, H.,

- (Eds) (2008), *Institutions and environmental change, Principal findings, applications and research frontiers*, The MIT Press.
- Giddens, A., (1984), *The constitution of society*, Polity Press
- Hamouda, L., Hipel, K.W., Kilgour, D.M., and J.L.The, (2004), Adaptive management of salmon aquaculture in British Columbia, IEEE International Conference on Systems, Man and Cybernetics, 10-13 October 2004, The Hague, The Netherlands, pp.5031-5037.
- Hardin, G. (1968), The tragedy of the commons, *Science*, 162, No. 3859, pp.1243-1248.
- Hajer, M.A., (2003), Policy without polity? Policy analysis and the institutional void, *Policy Sciences*, Vol.36, pp.175-195.
- Hajer, M.A., and H. Wagenaar, (Eds) (2003), *Deliberative policy analysis, Understanding governance in the network society*, Cambridge University Press.
- Healey, P., (2006), *Collaborative planning, Shaping places in fragmented societies*, 2<sup>nd</sup> Edition, Palgrave MacMillan.
- Huitema, Dave., Meijerink, Sander. (2009-forthcoming), *Realizing water transitions. The role of policy entrepreneurs in water policy change. Introduction of the special feature in preparation for Ecology and Society*.
- Imperial, M.T., (1999), Institutional analysis and ecosystem-based management: The Institutional analysis and development framework, *Environmental management*, Vol.24, No.4, pp.449-465.
- Kofinas, G.P., (2009), Adaptive co-management in social-ecological governance, as Chapter 4, pp.77-101, in Chapin, F.S. III, Kofinas, G.P., and Folke, C., (Eds), (2009), *Principles of ecosystem stewardship, Resilience-based natural resource management in a changing world*, Springer.
- Kooiman, J., (2003), *Governing as governance*, London: Sage.
- Lebel, L., J. M. Anderies, B. Campbell, C. Folke, S. Hatfield-Dodds, T. P. Hughes. and J. Wilson, (2006), Governance and the capacity to manage resilience in regional social-ecological systems. *Ecology and Society*, Vol. 11, No.1 ([www.ecologyandsociety.org/vol11/iss1/art19/](http://www.ecologyandsociety.org/vol11/iss1/art19/)).
- Manuel-Navarrete, D., Gomez, J.J., and G. Gallopin, (2007), Syndromes of sustainability of development for assessing the vulnerability of coupled human–environmental systems. The case of hydrometeorological disasters in Central America and the Caribbean, *Global Environmental Change*, Vol.17, pp.207–217.
- Metzger, M.J., Leemans, R., and D. Schroter, (2005), A multidisciplinary multi-scale framework for assessing vulnerabilities to global change, *International Journal of Applied Earth Observation and Geoinformation*, Vol.7, pp.253-267.
- Mitchell, R.B., (2008), Evaluating the performance of environmental institutions: What to evaluate and how to evaluate it?, Chapter 3, pp.79-114, in Young, O.R., King, L.A., and Schroeder, H., (Eds) (2008), *Institutions and environmental change, Principal findings, applications and research frontiers*, The MIT Press.
- Olsson, P., Folke, C., and T.Hahn, (2004), Social-ecological transformation for ecosystem management: the development of adaptive co-management of a wetland landscape in Southern Sweden, *Ecology and Society*, Vol.9, No.4, ([URL:http://www.ecologyandsociety.org/vol9/iss4/art2](http://www.ecologyandsociety.org/vol9/iss4/art2))
- Olsson, P., Folke, C., and Berkes, F., (2004), Adaptive co-management for building resilience in social-ecological systems, *Environmental Management*, Vol.34, No.1, pp.75-90.
- Olsson, P., L. H. Gunderson, S. R. Carpenter, P. Ryan, L. Lebel, C. Folke, and C. S. Holling. (2006), Shooting the rapids: navigating transitions to adaptive governance of social-ecological systems, *Ecology and Society*, Vol.11, No.1. ([www.ecologyandsociety.org/vol11/iss1/art18/](http://www.ecologyandsociety.org/vol11/iss1/art18/))
- Ostrom, E., (1990), *Governing the commons: The evolution of institutions for collective action*, Cambridge University Press, New York.

- Parmesan, C. and Yohe, G., (2003), A globally coherent fingerprint of climate change impacts across natural systems, *Nature*, Vol.421, 2 January 2003, pp.37-42 ([www.nature.com/nature](http://www.nature.com/nature)).
- Pretty, J., and Ward, H., (2001), Social capital and the environment, *World Development*, Vol.29, No.2, pp.209-227.
- Rammel, C., Stagl, S., and H.Wilfing, (2007), Managing complex adaptive systems – A co-evolutionary perspective on natural resource management, *Ecological Economics*, Vol.63, pp.9-21.
- Scott, J.C., (1998), *Seeing like a state – How certain schemes to improve the human condition have failed*, Yale University Press.
- Vatn, A., (2009), An institutional analysis of methods for environmental appraisal, *Ecological Economics*, Vol.68, pp.2207-2215.
- Vreugdenhil, H., Slinger, J.H., Smits, A., Kater, E., (2008), *Impacts of governance styles on river restoration in NW Europe. Paper for the conference of the International Association of Impact Assessments*. Perth, Australia, 4-11 May.
- Young, O.R., (2008), Building regimes for socioecological systems: Institutional Diagnostics, as Chapter 4, pp.115-144, in Young, O.R., King, L.A., and Schroeder, H., (Eds) (2008), *Institutions and environmental change, Principal findings, applications and research frontiers*, The MIT Press.
- Young, O.R., King, L.A., and Schroeder, H., (Eds) (2008), *Institutions and environmental change, Principal findings, applications and research frontiers*, The MIT Press.
- Walker, B., and Meyers, J.A., (2004), Thresholds in ecological and social-ecological systems: a developing database, *Ecology and Society*, Vol.9, no.2, ([www.ecologyandsociety.org/vol9/iss2/art3](http://www.ecologyandsociety.org/vol9/iss2/art3)).