Biocomplexity – Conceptual Challenges of Institutional Analysis in Biodiversity Governance

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Introduction

Two important issues have emerged from recent research on institutions that govern the use and the conservation of biodiversity: (1) biodiversity governance involves a system of diverse institutions that constrain and motivate interactions between human and ecological systems at a multitude of scales – institutions contain a number of mechanisms to respond to social heterogeneity and biophysical complexity; and (2) such institutions frequently comprise a number of different governance structures such as incentive based mechanisms and reciprocal relationships that regulate different aspects of the human-ecosystem interface.

Institutions are regulatory mechanisms at the interface between ecological and social systems (Gatzweiler and Hagedorn 2002). They are sets of rules and regulations that constrain and motivate actors to interact with ecosystems and other human beings in certain ways. Institutions are also referred to as the 'rules of the game'.

Achieving an adequate level of biodiversity conservation and sustainable use practices requires significant modifications in the current institutional arrangements. Designing those measures requires a sound understanding not only of the natural processes that determine an ecosystems reaction to human activities, but also of the processes and factors that shape the evolution of institutions. How can we describe and explain the dynamic relationship between human-ecosystem interactions on the one hand, and the evolution of institutional arrangements on the other? What are the factors that lead to the emergence of certain

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arrangements and under what circumstances will a specific change in the arrangement produce the desired outcomes?

Institutional analysis is a key to approaching questions of natural resource governance and has yielded significant insights on the dynamics and impacts of human-ecosystem interactions, such as the sustainable management of common pool resources through collective arrangements. Nevertheless institutional analysis still faces a number of problems. Most importantly these relate to the limits to comparability of empirical analysis and the consistent analysis and theorizing across different levels of social analysis and human organization. These problems are aggravated by the complexity of the interactions and interdependencies that affect the state of biodiversity. In the absence of a general theory on natural resource governance that could guide our analysis, we must resort to the heuristic and analytical tools that have been applied to other fields of natural resource management and seek to develop ways and means to deal with the complexity inherent in the analysis of biodiversity governance.

The objective of this paper is to develop an analytical tool for the operationalization of such research. We suggest that the identification and careful stylization of typical use-perspectives on biodiversity is a useful means to facilitate empirical, comparative analysis as well as it will enrich conceptual approaches on multi-level institutional analysis. In developing use-perspectives as an analytical tool, we seek to strike a balance between abstraction – a precondition for theorizing – and the account of complexity – needed for a meaningful reflection of the factors determining the success or failure of institutions for sustainable biodiversity governance.

The following section reviews the emerging literature on institutional analysis of biodiversity governance and motivates the need for a method of careful abstraction. Section three discusses frequently applied approaches to institutional analysis of resource governance and shows how these are likely to be overstrained in the absence of a tool for abstraction and simplification of analysis. Section four presents the use-perspectives approach and demonstrates how perspectives can be constructed step by step, using familiar examples of research on agricultural biodiversity. Section five discusses possible applications of the use-perspectives approach

Sources of Complexity in Biodiversity Governance

Biodiversity is not a resource in the commonly applied sense. The term describes a broad number of different resource uses based on genes, species and ecosystems that may be more adequately referred to as ecosystem goods and services. Ecosystem goods and services are human benefits generated by ecosystem functions and appropriated through interactions between human and ecological systems. DeGroot et al (de Groot et al. 2002) define ecosystem functions as the capacity of natural processes and components to provide goods and services that satisfy human needs, directly or indirectly (de Groot 1992)[3]. They further establish four primary categories of ecosystem functions: *regulation functions* and *habitat functions* are essential to the maintenance of natural processes and are conditional for provision of *production functions* and *information functions.* Regulation functions provide direct (clean air and water) and indirect (maintenance of soil productivity) services to human beings; habitat functions provide refuge and reproduction habitats for in-situ conservation of genetic resources and the reproduction of species that are harvested (e.g. for fishing); production functions provide mainly direct benefits such as food and raw materials; and information functions include educational, cultural, aesthetic and other goods and services (see table 1). Daily (1999) further mentions the preservation of options – the maintenance of the ecological components and systems needed for future supply of these goods and services and others awaiting discovery – as important function. Table 1 provides an overview over these functions

Functions, goods and services of natural and semi-natural ecosystems		
Functions	**Ecosystem Processes and Components**	**Examples of Goods and Services**
Regulation Functions Maintenance of essential ecological processes and life support systems		
1 Gas regulation	Role of ecosystem in the bio-geochemical cycles (e.g. CO_2/O_2 balance, ozone layer)	1.1 UVb-protection by O_3 (preventing disease) 1.2 Maintenance of (good) air quality 1.3 Influence on climate (see also function 2.)
2 Climate regulation	Influence of land cover and biological mediated processes (e.g. DMS-production) on climate	Maintenance of a favorable climate (temp., precipitation, etc) for, for example, human habitation, health, cultivation
3 Disturbance prevention	Influence of ecosystem structure on dampening environmental disturbances	3.1 Storm protection (e.g. by coral reefs) 3.2 Flood prevention (e.g. by wetlands and forests)
4 Water regulation	Role of land cover in regulating runoff and river discharge	4.1 Drainage and natural irrigation 4.2 Medium for transport

[3] The Convention on Biological Diversity defines biodiversity in analogous way as “the long-term or permanent qualitative or quantitative reduction in components of biodiversity and their potential to provide goods and services, to be measured at global, regional and national levels”.

5 Water supply	Filtering, retention and storage of fresh water (e.g. in aquifiers)	Provision of water for consumptive use (e.g. drinking, irrigation and industrial use)
6 Soil retention	Role of vegetation root matrix and soil biota in soil retention	6.1 Maintenance of arable land 6.2 Prevention of damage from erosion / siltation
7 Soil formation	Weathering of rock, accumulation of organic matter	7.1 Maintenance of productivity on arable land 7.2 Maintenance of natural productive soils
8 Nutrient regulation	Role of biota in storage and recycling of nutrients (e.g.N,P,K)	Maintenance of healthy soils and productive ecosystems
9 Waste treatment	Role of vegetation and biota in removal or breakdown of xenic nutrients and compounds	9.1 Pollution control/detoxification 9.2 Filtering of dust particles 9.3 Abatement of noise pollution
10 Pollination	Role of biota in movement of floral gametes	10.1 Pollination of wild plant species 10.2 Pollination of crops
11 Biological control	Population control through trophic-dynamic relations	11.1 Control of pests and diseases 11.2 Reduction of herbivory (crop damage)
Habitat Functions Providing habitat (suitable living space) for wild plant and animal species		
12 Refugium function	Suitable living space for wild plants and animals	Maintenance of biological & genetic diversity (and thus the basis for most other functions)
13 Nursery Function	Suitable reproduction habitat	Maintenance of commercially harvested species
Production Functions - Provision of natural resources		
14 Food	Conversion of solar energy into edible plants and animals	14.1 Hunting, gathering of fish, game, fruits, etc. 14.2 Small-scale subsistence farming & aquaculture
15 Raw materials	Conversion of solar energy into biomass for human construction and other uses	15.1 Building & Manufacturing (e.g. lumber, skins) 15.2 Fuel and energy (e.g. fuel wood, organic matter) 15.3 Fodder and fertilizer (e.g. krill, leaves, litter).
16 Genetic resources	Genetic material and evolution in wild plants and animals	16.1 Improve crop resistance to pathogens & pests 16.2 Other applications (e.g. health care)
17 Medicinal resources	Variety of (bio-)chemical substances in, and other medicinal uses of, natural biota	17.1 Drugs and pharmaceuticals 17.2 Chemical models & tools 17.3 Test- and essay organisms
18 Ornamental resources	Variety of biota in natural ecosystems with (potential) ornamental use	Resources for fashion, handicraft, jewelry, pets, worship, decoration & souvenirs (e.g. furs, feathers, ivory, orchids, butterflies, aquarium fish, shells, etc.)
Information Functions - Providing opportunities for cognitive development		
19 Aesthetic information	Attractive landscape features	Enjoyment of scenery (scenic roads, housing , etc.)
20 Recreation	Variety in landscapes with (potential) recreational values	Travel to natural ecosystems for eco-tourism, outdoor sports
21 Cultural and artistic information	Variety in natural features with cultural and artistic features	Use of nature as motive in books, film, painting, folklore, national symbols, architect., advertising, etc
22. Spiritual and historic information	Variety in natural features with spiritual and historic value	Use of nature for religious or historic purposes (i.e. heritage value of natural ecosystems and features)
23 Science and education	Variety in nature with scientific and educational value	Use of natural systems for school excursions, etc. Use of nature for scientific research

Table 1: Functions, goods and services of natural and semi-natural ecosystems
Source: De Groot et al 2002 (adapted from Costanza et al, (1997), de Groot (1992), de Groot et al, (2000).

The concept of ecosystem goods and services has a number of implications that show the complex tasks of biodiversity governance.
First, human benefit from ecosystems occurs at many different scales, involves a multitude of flows and interactions between human and ecological systems and a broad range of actor groups. The provision of goods and services depends on several, often interdependent, ecosystem functions occurring on different ecological scales that in turn differ from the scales of human appropriation and levels of decision making. Food production, for instance depends on the maintenance of soil productivity on a local scale; regionally it is influenced by climate regulation and pathogen populations; while on a global scale the maintenance and accessibility of genetic resources for plant breeding is becoming increasingly relevant for maintaining the productivity in a sufficient number of productive agro-ecosystems worldwide. This means that biodiversity governance involves a multitude of actor groups that is equally diverse and heterogeneous. Some goods and services may be consumed exclusively by a small local community, while others involve a broad number of different groups, some of which might not even be aware of their benefit. Some benefits take place across large areas. Many goods such as crops, livestock, fish, and medicines are traded internationally, so consumer preferences can impact on biodiversity far away without buyers realizing it. (Vermeulen 2004). Decision making on biodiversity – be it for the appropriation of goods and services or to take measures for conservation – takes place at all levels of social organization (from household to international). And often decisions taken by one group of actors may lead to an impact on functions that are necessary for goods and services used by an entirely different group that takes its decisions in a different action arena (Swanson 2003).
Many scholars have argued therefore that this diversity of relationships requires and equally diverse system of institutions. Ashby (1960)developed the ‘Law of Requisite Variety’ according to which any regulative system needs as much variety in the actions it can take as exists in the system it is regulating. Ostrom (1998b) argues that complex resource systems and biodiversity can be successfully maintained by complex, polycentric, multi-layered governance systems that have a variety of response mechanisms. Each system requires adequate and reliable mechanisms for detecting and understanding change (data collection and monitoring) and reacting appropriately at the appropriate scale of human activity (Gatzweiler 2005).

Second, table 1 shows that ecosystem goods and services vary in their properties. Therefore different governance structures are required for their allocation and management. Private goods such as food, raw materials or biomass fuels are more adequately allocated through markets than public goods such as beautiful landscape, clean air or climate regulation. Common pool resources that are characterized by low feasibility of exclusion and high rivalry in consumption are often managed through reciprocal relationships. The attributes of some goods vary depending on the type and context of use. Seed materials are a form of genetic resources that is used as an intermediary product for food production. In the short term, seed has the character of a private good since it can be planted only once in a given vegetation period. In the long run, however, due to its self reproducing capacity, seed may be better characterized as a club or public good since its rivalry in consumption decreases with time and access to a small quantity may be sufficient to reproduce and use a specific variety (Smale et al. 2004). For users in the biotechnology sector seed of a given variety is a source of potentially valuable genetic information. However, prior to its revelation through research activities this value is highly uncertain. As soon as it is decoded and its value identified it becomes an information resource that has the characteristics of pure public good (Janssen 1999), (Swanson and Goeschl 2000).

Institutions for biodiversity governance must thus include a variety of governance structures for transactions relating to goods and services with different properties. Institutional diversity is not only important with respect to the multitude scales of interaction and appropriation, but also with respect to a careful fitting of governance structures to the properties of goods and services and their transactions.

Furthermore, the type of governance structure is not only relevant with regard to the properties of the ecosystem good or service at hand, its impact also depends on the institutional context. Institutions that govern human ecosystem relationships do not exist in isolation from other institutions. They are embedded in a broader societal context that includes informal institutions such as customs, traditions, norms and worldviews of actors; the formal institutional environment – property rights, bureaucracies and the judiciary system; and governance structures for other transactions that may interact with governance structures for biodiversity. Williamson (2000) has described these as the four levels of social analysis where higher levels impose constraints on institutional change at lower levels. Informal institutions represent the level of social embeddedness. Institutional change at this level occurs very slowly.

(de Groot et al. 2002) note that ecosystem goods and services describe the (potentially) useful aspects of natural ecosystems to humans. They represent an ‘anthropocentric translation of basic ecological structures into value-laden entities' (ibid). This translation is not only the result of an actor group's direct benefit, but it is also an expression of the way it is embedded in its broader societal context. "Different groups, be they within a given society, across different societies and through time, attribute different values to the environment. This stems, in part, from the complexity of the interrelationships between the biotic and physical components of ecosystems, and the fact that these relationships are open to alternative interpretations." (Hayward, 1995: 218, cited in Baker 2001). Actor groups are not only heterogeneous with regard to their preferences – the values they attribute to goods and services, but also in their logics of action. Members of communities in which resource governance is based on cooperative or reciprocal behavior will react differently to external incentives than actors who have a tradition in market based exchanges. Their decision making may not follow the simple logic of benefit maximization and cost minimization (Ostrom et al. 1999).

For instance, the implementation of market based mechanisms for the transfer of genetic resources to users in the biotechnology sector has often been suggested as means to channel an adequate payoff to the providers of genetic resources and create incentives for conservation (Heal 2004; Heal 1999). However, the introduction of an incentive based mechanism can under certain conditions disturb existing systems of resource governance in such a way that it increases the danger of resource depletion. If the existing institutional arrangement includes a mixture of self-interested and cooperative behavior, the introduction of an incentive mechanism will lead to an expansion of self-interested behavior and to a reduction in cooperative behavior. This is because the market expands the number of actors involved, and individuals will no longer assume that their behavior has an impact on the behavior of others and consequently they will not expect reciprocity by others. If genetic resources are maintained through a reciprocal arrangement, such as often is the case in indigenous and local communities, the introduction of a market mechanism may lead to their loss despite the availability of monetary incentives (Dedeurwaerdere 2005).

To summarize, we can identify at least three sources of complexity in institutional analysis of biodiversity governance.

- Biodiversity describes the biological components of a complex system of ecosystem functions. These functions are the basis for the delivery of ecosystem goods and services. Human interaction with ecological systems to appropriate these services occurs at different natural and human scales. Institutional analysis has to account for this complex web of interaction and must integrate several scales of social analysis.

- Human benefit from biodiversity covers a broad range of ecosystem goods and services that differ widely with respect to their transaction properties. Public goods require different governance structures than private goods. Depending on the type of appropriation physically identical units may serve as different goods or services with different properties. This variance in properties and the way it affects transactions leads to the development of a plurality of governance structures for a specific component of biodiversity or a set of ecosystem functions.
- The behavior of actors not only depends on their direct relationships with the ecological system, but also the broader institutional and societal context. The context has a strong influence on the actor's logic of action. Therefore specific governance structures will lead to different actor responses depending on the context and its impact on the logic of action.

These interrelationships determine the evolution of institutional arrangements for biodiversity governance. They will also determine the outcome of changes in the institutional arrangement that aim at the conservation of biodiversity. Regardless whether conservation targets individual species, whole ecosystems or the establishment of sustainable use practices, measures must be based on a sound understanding of the complexity of human-ecosystem interactions.

Institutional Analysis of Biodiversity Governance

Institutional analysis of biodiversity governance requires first a careful conceptualization of the interface between human and economic systems. The way this unit of analysis is defined determines how causal models of the relationship between explanatory variables are constructed. The main problem in the case of biodiversity is to find a way forward in structuring the maze of complexity outlined above. Nevertheless, in the absence of a general theory on institutions for resource management there is little guidance on how to approach analysis. Ostrom (2003) has noted that the richness of potentially relevant factors makes it unlikely that a general theory of common pool resource management will be developed. The power of collective action theory is related to its reduction to a single factor differentiating goods and affecting the outcome of collective action – that of difficulties in excluding unauthorized access to a resource. Such a theory is however only valid for a subset of goods. The introduction of new distinctive factors leads to the development of more specialized theories. Ostrom expects the development of the "family tree" of specialized collective action theories, rather than a general theory that is valid for all kinds of collective action problems.

A commonly applied solution to this dilemma is the use of a research heuristic or generally formulated analytical framework. Rather than serving as theory in their own right, such frameworks seek to provide a 'metatheoretical language' that can be used to select and compare the relevant theories needed to explore complex problems, such as the manifold aspects of conservation and sustainable use of biodiversity. Frameworks provide the most general set of variables that should be used to analyze all relevant settings in an attempt to identify the universal elements that any relevant theory would need to include (Ostrom 2005). A number of frameworks exist that are designed to investigate the complex interaction between human and ecological systems. We will base our discussion on Hagedorn's framework for the analysis of *Institutions of Sustainability* (IOS) (Hagedorn et al. 2002, Gatzweiler and Hagedorn 2002, Gatzweiler et al. 2005) and Ostrom's *Institutional Analysis and Development Approach* (IAD) (Ostrom et al. 1994, Ostrom 1998a and 2005)

Both of these frameworks emphasize the conceptual idea that the physical attributes of natural resources, the attributes of actor groups managing those resources and the currently valid institutional arrangement are the essential categories of explanatory variables in the analysis of the development of institutions. The units of analysis in Hagedorn et al's IOS framework are transactions affecting the natural environment and the ecological system. These transactions can be *producing* environmental problems by production and consumption activities or *diminishing* environmental problems by self organization or government policies (Hagedorn et al. 2002). The IOS framework was originally developed with a focus on agro-environmental co-ordination for sustainable resource management. Agriculture has traditionally been operating at the interface of social and ecological systems, and farmers have developed specialized skills to manage the environmental functions provided by the ecosystem. Sustainability means that both systems maintain their functionality over time and are able to adapt to external shocks (i.e. that both systems are resilient in the way they are interacting) (Gatzweiler and Hagedorn 2002).

Due to its broad conception we believe that the framework can be expanded to cover the whole range of interactions that relate to the appropriation of ecosystem services including all transactions that impact on the underlying ecosystem functions and thereby (positively or negatively) affect the capacity of the ecosystem to continue providing ecosystem goods and services. However, one transaction will almost certainly influence a number of ecosystem functions and the effect will differ for different ecosystem goods and services. This is most obvious in extreme changes to the environment, such as the conversion of forest to agricultural land, which obviously increases the capacity of the (agro-) ecosystem to provide food, while it destroys its capacity to provide forest products or retain and filter water. Our intention is to also capture the more subtle consequences of human actions, for instance the impact of a change from conventional to organic farming practices. Such analysis must work with a more differentiated conception of causality and apply a number of scales and resolutions to measure changes and relate them to models of causality across the interface of human and ecological systems. The IOS framework proposes four groups of determinants of institutional change: (1) features and implications of the transactions related to nature and the ecosystem; (2) characteristics and objectives of the actors involved in those transactions; (3) the design and distribution of property rights on nature components; and (4) governance structures for agro-environmental relations (Hagedorn et al. 2002). Rather than identifying the exogenous and dependent variables for the analysis of institutional arrangements, the IOS reflects the dynamic interdependence between changes in the four components that determine interactions between social and ecological systems.

The core unit of analysis in Ostrom's IAD framework is the action arena in which participants take different types of decisions under the conditions of a specific action situation. The action arena is affected by three sets of exogenous variables: the attributes of the biophysical world, attributes of the community within which the action arena is placed, and the set of rules used by the participants to order their relationship. These categories contain a large number of potentially relevant variables and thus a sheer unlimited number of combinations exists that may be relevant to explain the outcomes in any particular action arena. Ostrom argues, that 'the analyst will use theories that are compatible with the framework in order to generate predictions about expected patterns of relationships. Over time, empirical research will show, which theories are most applicable to explain a particular problem' (Ostrom 2005). Specific causal models are used to make precise assumptions about a limited set of parameters and variables and to systematically explore their consequences in a given setting. Models can yield predictions about patterns and relationships that can be tested empirically, or they can serve as guide for the exploration of complementary or alternative explanations.
Next to the *spatial levels* of political jurisdiction (household, community, regional, national and international), action arenas are further differentiated according to the *conceptual levels* of human choice. *Operational choices* are decisions relating to human activities that are often decided on a day to day basis. Decision making on the rules that guide and restrict operational choices are taken at a *collective choice* level. At still a different conceptual level collective choice rules are the outcome of *constitutional choices* structured by constitutional rules.

Interactions between human and ecological systems are the result of operational choices. Such choices are made on every jurisdictional level. The rules that apply to the choices at the interface are thus taken on a collective choice level, subject to higher order rules established on a constitutional choice level. In order to understand the structure, processes and outcomes of complex polycentric governance systems one needs to be aware of the operational, collective and constitutional choices taken at each of the jurisdictional levels of human choice (Gibson et al. 2000).

The IAD framework, compatible theories, and families of causal models provide tools for analyzing institutional arrangements for sustainable resource management at multiple scales and levels of analysis. Nevertheless, the complexity of human interactions and the diversity of human-ecosystem relationships place difficult challenges before the researcher. The large number of potentially relevant factors and the interactions among multiple actor groups with different objectives inevitably lead to a degree of complexity that is difficult, if not impossible to operationalize. In many cases there will be no adequate theory or causal model available that allows incorporating new explanatory factors that may be revealed by empirical research. Applying the IAD framework to support the development of more general explanations of institutions of natural resource management is anything but trivial. Ostrom's recommendation to build a family tree of closely related theories is reasonable in the light of the complexities that research on CPR and other collective action problems has revealed, but it puts the researcher, particularly the theorist into a difficult situation. Inevitably using the IAD framework as heuristic for including new factors in theoretical analysis will generate a large number of highly context specific explanations. As such explanations will be based on conclusions from case studies, they will be relevant primarily for the sample under consideration, rather than applying more generally (Agrawal 2001). As theories of collective action phenomena in biodiversity governance, they have little explanatory power beyond the specific empirical setting in which they were conducted.

What is thus needed is a method of adequate abstraction from the rich empirical knowledge that has been generated by case study research on institutional arrangements for natural resource management.

One approach to developing more general explanations that has been used by many commons scholars the comparison of larger sets of case studies in order to derive a collection of conditions or facilitating factors that are critical to the sustainability of commons institutions. Agrawal (2001) has analyzed three of these meta-studies and synthesized the facilitating conditions identified. He derives four categories of *empirical* variables that are key to explaining successful management: (a) characteristics of resources; (b) nature of groups that depend on resources; (c) particulars of institutional regimes through which resources are managed; and (d) the nature of the relationship between a group and external forces and authorities such as markets, states and technology. He discusses three problems of method that make it unlikely that the generation of lists of variables will promote the development of a general theory of the commons. First, in many cases little attention is given to factor-context interactions. Specific factors may be relevant only under certain contextual conditions and have no, or even opposite influences under different conditions. Single case studies can often afford to ignore the context of their setting as long as it remains constant for the range of the study. Across studies, however, there may be substantive variance in context, which has an impact on the effect of the variables explicitly studied. Second, in many studies no causal model to be tested is specified. This can lead to results emphasizing irrelevant factors, while other relevant ones are being omitted. Further, problems of endogeneity are difficult to identify in such cases. Third, different factors or combinations of factors may be responsible for the observed outcomes. This problem of multiple causation – particularly in single case analyses – makes it difficult to identify how factors impact and how strong their influence is compared to other factors. Agrawal suggests that the only way to solve these problems is to carefully design comparative studies by selecting cases 'for the variation they represent on theoretically significant variables' (Agrawal 2001). This means that the researcher has to have both knowledge of the theoretical basis on which to select variables, and knowledge of the particular case settings in order to adequately operationalize the variables for analysis. To address this problem the researcher needs a model of causality that guides the selection of potentially relevant variables, but also information on their expected significance in the actual study situation in order to further reduce the number of variables.

Resource-Use Perspectives

The main idea of our suggested approach is to reduce complexity through the stylization of common resource-use perspectives on various aspects of biodiversity governance. Resource-use perspectives should serve as analytical tool for comparative institutional analysis, following the heuristics of the IAD and IOS frameworks, across cases as well as across the spatial levels of human decision making (household, community, district, state, federal, regional, and international – (see Gibson et al. 2000). The intent is thus, to define a common analytical structure, that is general enough to allow for comparison along the principles of a certain type of resource use, while it is flexible enough to capture the variance that we can expect when we are analyzing across a number of settings.

A resource-use perspective is defined by a group or series of transactions that typically occur simultaneously or in close conjunction and involve at least one identical actor or actor group (e.g. commercial farmers who buy grains as seed and sell grains as food). The reason for clustering transactions is that they either do not occur in isolation, or they are mutually interdependent, because one transaction is contingent to another. A commercial farmer would not buy seed if he would not have the plan of selling the produce. In such cases we have to allow for the existence of influences and causal ties between the transactions. These interdependencies complicate or even prohibit their analysis in isolation. The grains a farmer buys for use as seed and the ones he sells as food have identical physical attributes. However, the farmer's perception of these may differ substantially. A hard grain shell may indicate a high germination rate of seed, but it may be also be detrimental to its quality as food source. If so, the farmer faces a dilemma. He can buy high quality seed and accept a likely lower price for his produce, or he can opt for high food quality and accept the risk of lower productivity. If we analyze the transaction of buying seed in isolation, how are we to understand which of the options the farmer prefers?

This is to say, that many aspects of decisions regarding a transaction X may in fact be related to attributes of the good that are relevant only in the context of another transaction Y. The actor already has Y in mind when performing transaction X. Thus there is an implicit link between two transactions that would be ignored if we were to analyze each transaction in isolation. While it seems fairly easy to include the concern for a hard grain shell in an explanation of a farmer's preferences, things quickly get more complicated if the attributes affecting a transaction become more subtle.

For instance, all seed or planting materials are characterized by the fact that the majority of a variety's attributes are not readily observable when the transaction between a seed supplier and a farmer takes place. This is due to limits in the observability of the genotype of a plant. Even in full maturity, the phenotype of a plant expresses only a part of its genotype as some characteristics are only expressed in certain vegetative states or under specific environmental conditions. This natural phenomenon leads to a problem of transparency in the transactions of seed and planting materials and, subsequently, to a considerable level of risk for the buyer. At the moment the transaction takes place, the buyer is unable to check if the characteristics advertised by the seller are really present in the materials and the farmer does not know if they will be expressed under the specific environmental conditions present on his fields.

For the second transaction, the selling of grains as food, many of the productive properties of a variety, such as pathogen resistance or adaptation to certain environmental stresses are irrelevant for the quality of food grains. Nevertheless, some quality attributes may still be affected by a transparency problem. Nutrient composition, vitamin contents and other attributes are, if at all, only indirectly observable in the grain. When buying seed, the farmer not only faces uncertainty about the attributes that will directly affect his production activity, but also about those attributes of concern to the buyer of his product. If, for example, the market regulation requires the farmer to provide detailed information about the quality attributes when selling the grain, he will have to ensure that the seed supplier provides reliable and complete information about these attributes when he is buying the seed. In this case, the first transaction (seed grain) is affected by the governance structure regulating the second (food grain).

To understand the interests and motivations of farmers as a specific user group of biodiversity resources, we need to develop an integrated concept that leads us to investigate not only the direct relationship between resource attributes and other exogenous factors on one transaction, but also the interdependencies between various transactions that are logically linked. The links between two transactions (or two sets of complementary transactions) are productive, transformative or consumptive activities that serve as channels through which an ecosystem good or service, is transferred from one transaction to another. Our example – we may view it as a simplified model of the commercial farming perspective – consists of two transactions (buying seed and selling food grains) and a productive activity (growing and harvesting food). We can think of numerous other transactions that are linked to agricultural production; renting or buying land, buying fertilizer and pesticides, investment in irrigation systems, to name but a few. While these all have an impact on food production they are not direct transactions of a biodiversity resource. Therefore, we may at this point regard them as contextual factors.

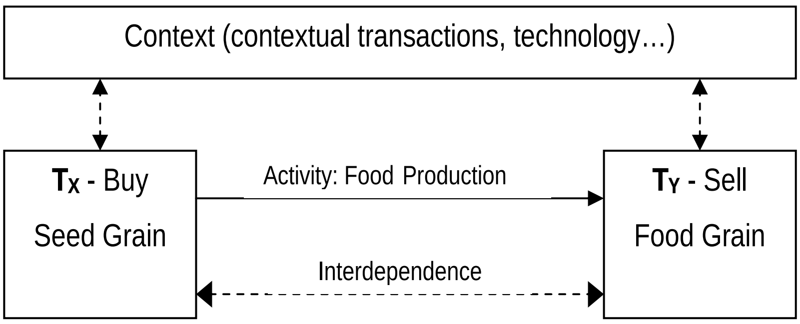

Figure 1: The biodiversity use perspective of commercial farmers

We know that this is true for all transfers of seed and planting materials, no matter where, when and between which actors they occur. If, for the moment, we neglect variances in the degree of transparency arising out of the specific properties of different species, we can make a number of very general conjectures about the institutional arrangements we expect to find for governing of seed and planting material exchange. First, we can anticipate some kind of an institutional mechanism to increase transparency and reduce risk for the buyer. Second, as the seller is likely to always have more information than the buyer, we can expect that the mechanism includes a provision that ensures a transfer of information to the buyer as part of the transaction. Third, this obligation to provide information will be enforced by a credible sanctioning mechanism, which can be triggered by the buyer (i.e. the buyer has access to formal or informal channel of third party enforcement).

One might argue that these are the fundamental elements of any market transaction; however our objective at this stage is not to make specific conjectures, but to display how we can link a conjecture about institutional arrangements to an observable attribute via a postulated causal relationship. In this case the causality would be as follows: (1) differences in genotype and phenotype of plants lead to a problem of decreased transparency; (2) low of transparency creates a problem of asymmetric information and increases risk for the buyer. Because of the causal relationship between transparency, information and risk, we postulate that (3) there will always be a mechanism that reduces risk for the buyer by means of an obligation to transfer information. This postulated correspondence will be a first element of the farmer-seed use perspective (Fig.2).

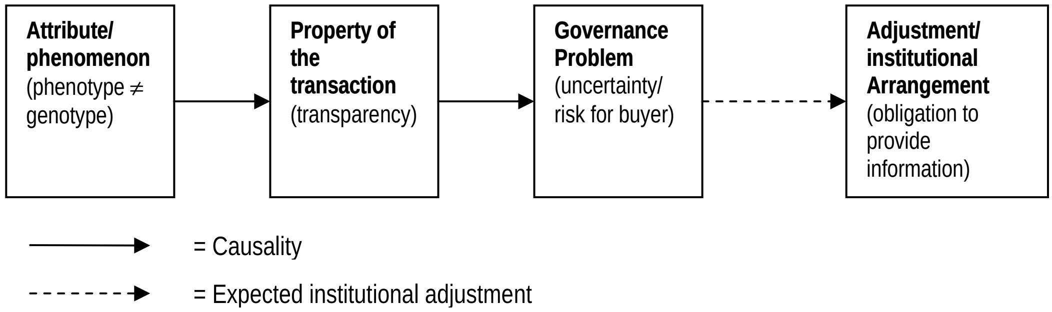

Figure 2: A mono-causal relationship linking a resource attribute to a transaction property and the resulting governance problem and the expected adjustment in the institutional arrangement.

Figure 2 also illustrates that, in order to establish the causal relationships that define a resource use perspectives we need to differentiate the biophysical attributes of the ecosystem good or service from the properties of the transaction. Attributes influence transaction properties, but the two are not the same.

Once we have established this distinction we can describe the relationship through causal link between the biophysical attribute and the property of the transaction on the one hand, and between the property of the transaction and the governance problem on the other[4]. In the above example, we argue that low transparency of seed transactions is a consequence of the natural fact that seed and planting materials do not readily display the genotype of a plant. This is only one factor that influences the transparency of a transaction. But as we argued above, biodiversity governance is characterized by a multitude of interacting factors and their influence on transactions resembles a complex web rather than the unidirectional and monocausal influence we described here. Furthermore, we have to acknowledge that the separation between the properties of a transaction and the resulting governance problem we made in Figure 2 does not adequately reflect reality. Governance problems do not occur in separation from transactions. The manifestation of the governance problem is however not only affected by the biophysical attributes influencing the transaction, but also by the social

[4] In this case the governance problem is a typical principal agent problem arising out of the asymmetry in information between the seller and the buyer. However the resource-use perspectives approach can be applied to other problems that are more common to environmental governance, such as coordination problems, knowledge transfer and social dilemma situations.

attributes of the actors performing it. Finally, the institutional context also influences the outcome through the restrictions imposed on the transactions on higher levels of social analysis. This means that even if we are able to establish the causal links between all relevant biophysical attributes and the transactions of a use perspective, we will merely develop an explanation that is context specific with regard to the social attributes and the institutional context.

One way to solve this problem would be to perform the same exercise for each of the three categories of variables, leading to a research logic as depicted in Figure 3.

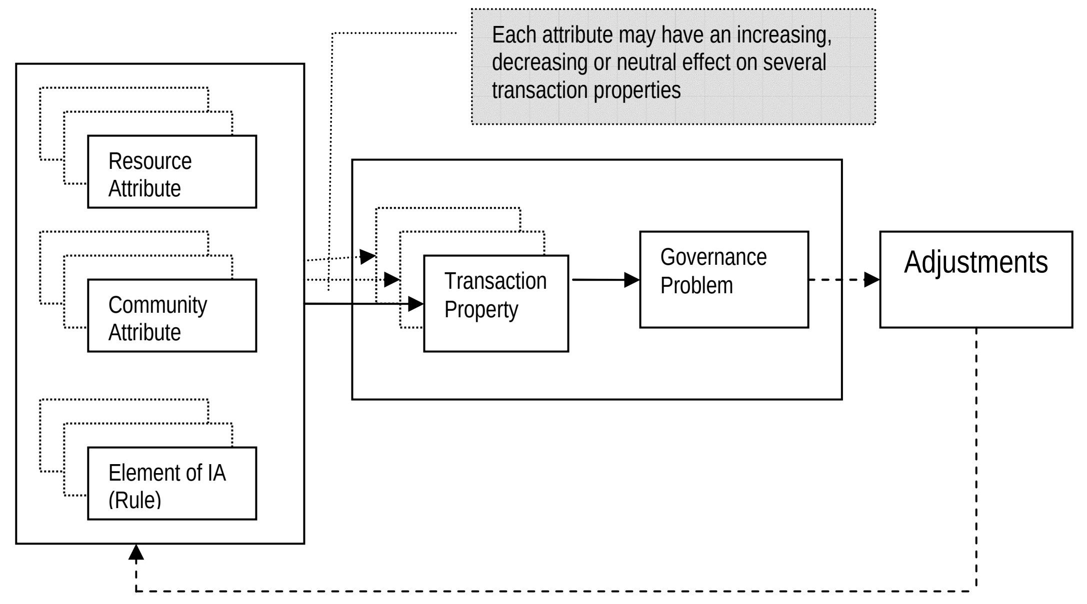

Figure 3: The system of multiple causalities and dynamic feedback

Nevertheless, this approach is flawed. It would only hold under the conditions of perfect independence between the variables in the three categories. In reality there are manifold interactions between these variables. Just as ecosystem goods and services are expressions of anthropocentric values attributed to ecosystem functions, we have to consider that the whole interface between human and ecological systems is essentially constructed by humans beings. This implies that the social attributes and the institutional context are expressions of the history of human interaction with the ecosystem. Any use perspective is the result of a long term co-evolution between human and ecological systems. Therefore we have to assume that significant overlaps exist between the conceptual categories and that variables and their causalities cannot be explicitly related to one single category.

On the other hand, we do know from empirical research that certain attributes do have a strong impact on the properties of a transaction and the institutional response to address governance problems arising out of these properties (Agrawal 2001). This knowledge can and should be used to refine future research and analysis. We propose to face this problem through an approach of double selection of explanatory variables. The first criterion should be the availability of a causal model that motivates the assumption of the variable's *relevance*. Causal models can be derived through consistent deduction from a theory, such as explanations based on natural sciences for biophysical attributes, as well as theories used in the social sciences.

The second criterion should be the empirical *significance* of the attribute, which can be derived from existing empirical studies. This double selection by causal relevance and empirical significance allows to reduce complexity and structure research. Causal relevance serves as a guide to identify and select variables from the unmanageable pool of potential factors, while empirical significance allows to rank these variable according to their expected explanatory value. Figure 4 represents the effect of this double selection applied to the farmer's use perspective discussed above.

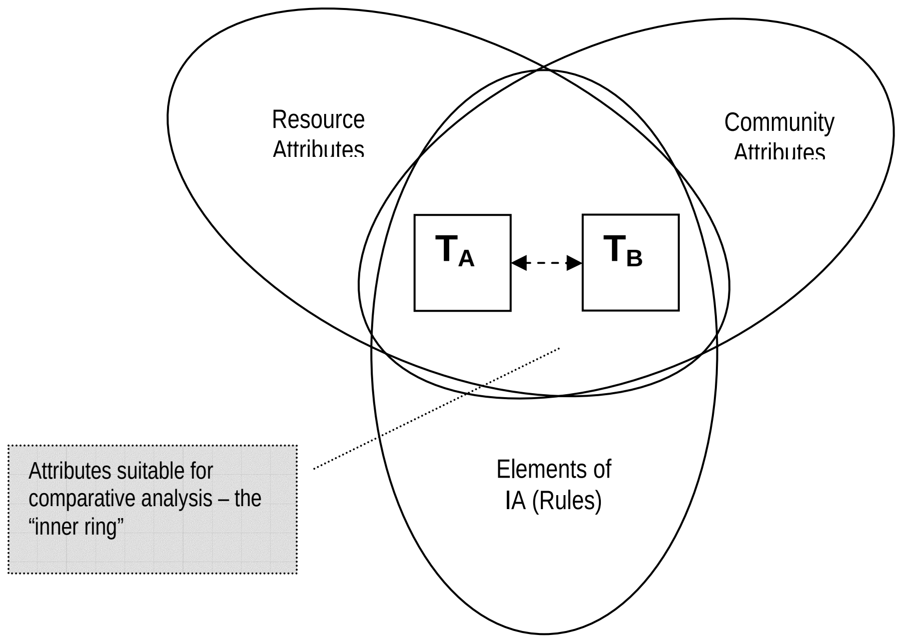

Figure 4: A resource use perspective and its exogenous variables

Variables that meet both criteria have a relatively higher potential of delivering meaningful explanations. They are therefore located in the inner circle around the transactions. Variables outside this circle are considered to have a lower potential of delivering a meaningful explanation. The impact of neither the inner nor the outer variables can be predicted with certainty. This is due to the problem of context specificity noted above. As soon as we concentrate our analysis on few or a single causal relationship, we will inevitably produce explanations that are highly context specific. We can picture that variables influencing the properties of a transaction are located on a cloud around this transaction in a way similar to location of electrons around an atom. Due to the problem of context specificity we cannot at the same time identify the position of variables within the cloud (i.e. the relevance and significance) while trying to derive general conclusions beyond the specific setting investigated. We can call this the ‘uncertainty principle of institutional analysis’. Just as the position of an electron can only be expressed in terms of probability, we can only approximate the explanatory potential of a variable.

Bundling transactions into resource use perspectives allows to increase the density of the inner circle. Variables relevant for a bundle of transactions are more likely to be in the inner circle and should be easier to identify. Focusing on this set of variables allows the construction of more complex causal models that apply to all those settings in which the use perspective can be found. Consequently we can expect a similar set of variables satisfying the criteria of relevance and significance. We can thus develop a standard sets of variables for the analysis of resource-use perspectives across a range of situations. Having tested this set, remaining variance can be attributed to other variables that may be relevant and significant in this particular context.

Discussion

At this point, resource-use perspectives are still at the stage of a thought experiment and further work is needed to develop an approach that is operational for research. Part of this work will be to test whether the procedure we have depicted above can be fruitfully applied to other problem settings. The representation of the farmer-use perspective, even though our representation is likely to be oversimplified, could for instance yield interesting insights in research on new forms of cooperation between farmers and plant breeders to enhance conservation and development of agricultural genetic resources. A comparison of farmer-use perspectives from different contexts (e.g. traditional agriculture, intensive farming, and organic farming) can point towards obstacles and potentials for such cooperation (Smale 1998).

Defining the resource-use perspective of traditional agriculture can build on a large body of interdisciplinary research (Brush 2000). This knowledge base should provide the necessary causal models and sufficient empirical data to perform a selection of variables that satisfies the two criteria of relevance and significance (e.g. Louette et al. 1997; Smale et al. 2004). Once this perspective is defined through a set of variables and causal models and confirmed by a number of existing studies, it can be used to design more precise empirical analysis. The resource use perspective allows targeting certain sources of variance in the selection of case study cites.

For example, research on traditional systems of seed management and seed exchange indicates that the type of crop has a decisive influence on the type of rules and habits that emerge within the seed system (Brush 1995). According to our example, we could hypothesize that the problem of transparency is expressed differently with different crop species. A potato tuber may reveal more of its characteristics than a grain of maize or wheat, leading to a different degree of transparency and eventually to a different institutional response. But testing such a hypothesis is difficult because traditional potato production and maize production exist in very different regions with different cultures and history. Under such circumstances it is arduous to avoid explanations that are highly context specific. A well defined resource-use perspective allows us to separate general from context specific elements of an explanation. With this separation in mind, it should be possible to develop a research design that allows a meaningful comparison of the settings and eventually testing of the hypothesized impact of the crop species' attributes on the institutional arrangement.

A second application of the resource-use perspective that merits exploration, is an integration of analyses across the spatial (or jurisdictional) levels of human decision making. From a methodological point of view this integration is difficult because we cannot aggregate preferences. Since Arrow's (1951) work on social choice, we know that it is impossible to scale up from individual preference functions to produce a group preference or public interest function. Insights on the logic of community based management of biodiversity cannot be applied to problems that demand cooperation at a global scale and vice versa. Among others, this leads to the problem that local interests and values are frequently ignored or misinterpreted in decision making at higher jurisdictional levels (Swanson 2003), (Vermeulen 2004). The advantage of the concept of resource-use perspectives is that it includes causal models that display the logic of interaction with the ecological system of different user groups. If we make this logic explicit, it can be used to test whether decisions taken at higher levels account for this logic. In this way, one could design tests for the compatibility of suggested approaches with the logic of resource use of a certain actor group.

Finally, on a different scale of social analysis, we can apply resource-use perspectives to explore the potential and limitations for implementing measures for conservation and sustainable use that arise out of the broader institutional and societal context. Any institutional arrangement is constrained by the context in which it is embedded. Resource-use perspectives may support efforts to identify these constraints and design adapted responses for implementation.

<table>
<tr><td colspan="2">Setting</td><td colspan="2" rowspan="2"></td></tr>
<tr><td>Same</td><td>Different</td></tr>
<tr><td>Analysis of constraints imposed by institutional and social context</td><td>Analysis of compatibility between the actor logic and decision making on different jurisdictional levels</td><td>Different</td><td rowspan="2">Level of social analysis</td></tr>
<tr><td>Statistical Comparative analysis</td><td>Qualitative comparative analysis</td><td>Same</td></tr>
</table>

Table 2: possible applications of resource-use perspectives for analysis

These applications are but hypothetical at the moment. In all the fields outlined above research from different disciplines and using various approaches and methods is being done. Further work will have to explore in which of these fields an approach building on the conceptual idea of resource-use perspectives is most complementary and deliver the most meaningful results.

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