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Analysis

Biocomplexity—conceptual challenges for institutional analysis in biodiversity governance

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ABSTRACT

Institutions for biodiversity governance are located at the interface of human and ecological systems. The analysis of such institutions is challenged due to addressing a multitude of complex interactions between these two systems occurring at different natural scales and levels of human organization. Due to this complexity, empirical analysis of biodiversity management often leads to context-specific explanations, providing little scope for comparative work or the development of more generalised, theory-based accounts. We aim at reducing complexity in understanding human–biodiversity relations, making cases comparable across sites, and propose that, in order to address complexity, we need a method of abstraction that leads to the development of a more structured analysis, based on selection of explanatory factors according to cconceptual models as well as empirical significance. We suggest that the stylisation of typical "resource use-perspectives" – the combination of typical transactions that are inextricably linked by the interest of the actor – can be a useful method for realizing appropriate model selection. In this paper, we provide an account of how use-perspectives can be developed and to what kind of analysis they can contribute, using the example of agrobiodiversity in grain as seed, food, or genetic material.

1. Introduction

Two important issues have emerged from recent research on institutions governing use and conservation of biodiversity. First, biodiversity governance involves a broad array of institutions that constrain and motivate interactions between human and ecological systems at a multitude of scales: from a gene to whole ecosystems (Millennium Ecosystem Assessment 2005). These institutions contain a number of mechanisms for responding to social heterogeneity and biophysical complexity. Second, 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' (North, 1990).

We propose use-perspectives as an analytical tool for biodiversity governance. With a highly complex resource like biodiversity problems of coordination and competing targets are faced on matters such as food production, conservation or breeding. The resource at stake is highly complex, equally so the human use of it. Institutions are at the interface between the natural environment and the actors putting it into use for different ends. Therefore, we observe a multitude of institutions aiming at regulating resource use. The use-perspective introduces actor's interest as an explicit analytical category to biodiversity governance research. Inclusion of the perspective of the actor's undertaking a certain use – implying thereby alternative transactions – helps to distinguish cases and, at the same time, makes them comparable across contexts. To understand the vast array of existing rules and regulations, in order to improve resource governance by crafting new institutions, we suggest (1) considering the interests of users, stressing their perspectives and aims; (2) capturing the properties of transactions as the basic analytical unit; and (3) making cases across settings comparable.

The normative background for our endeavor is the pledge of the Convention on Biological Diversity (CBD) to halt the loss of biodiversity through conservation and sustainable use practices, requiring significant modifications in current institutional arrangements (Jungcurt, 2008). Designing such measures requires a sound understanding of the interaction between the natural processes that determine an ecosystem's reaction to human activities and the processes and factors that shape institutions (Heal 1999, 2004). Institutional analysis is 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 (Ostrom, 1990; Ostrom et al., 1999). Nevertheless, institutional analysis still faces a

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number of problems. The comparability of different empirical analyses is limited and hinders consistent theorizing across different levels of social analysis and human organization: from the individual to the state. These problems are aggravated by the complexity of the interactions and interdependencies that affect the state of biodiversity. As we seek to develop ways and means to deal with the complexity inherent in the analysis of biodiversity governance, our investigation is guided by the heuristic and analytical tools that have been applied to other fields of natural resource management.

The objective of this paper is to develop an analytical tool for such research. We propose the identification and careful stylization of typical 'use-perspectives' on biodiversity by introducing actor interest as a core dimension as a means to facilitate empirical, comparative analysis as well as enriching conceptual approaches on multi-level institutional analysis. Interest as an explicit perspective for analyzing biodiversity governance research stylises certain uses and sequences of transactions in order to distinguish cases and make them comparable across contexts.

Existing frameworks generate a large number of highly context-specific explanations based on conclusions from case studies, primarily relevant for the sample under consideration, rather than applying more generally (Agrawal, 2001). Theories of collective action phenomena in biodiversity governance have little explanatory power beyond the specific empirical setting in which they were conducted as conceptual models are missing. What is thus needed is a method of adequate abstraction. Considering Agrawal's elaborate critique on missing conceptual models, we propose the approach "use-perspective" to allow for a systematic analysis of choice properties in biodiversity management.

The following section reviews the emerging literature on institutional analysis of biodiversity governance and clarifies the motivation behind the need for a new method of abstraction. Section 3 introduces transactions as the unit of analysis. Section 4 discusses commonly applied approaches to institutional analysis of resource governance and shows how results remain isolated findings in the absence of a tool for abstraction or simplification. Section 5 presents the use-perspectives approach and demonstrates how use-perspectives can be constructed step by step, using familiar examples from research on agricultural biodiversity. Section **6** discusses possible applications of the use-perspectives approach

2. Sources of Complexity in Biodiversity Governance

We have identified at least four sources of complexity in institutional analysis of biodiversity governance: (1) the interrelationships between ecosystem functions, (2) the coexistence of different kinds of transactions for physically identical units and (3) the broader institutional and societal contexts. (4) We elaborate on the challenge to capture the provision of goods and services by an ecosystem with institutional means lies at the heart of the analytical need to make case comparable for institutional learning.

Ecosystem services depend, first, on several, often interdependent, ecosystem functions occurring on different ecological scales, which in turn differ from the scales of human appropriation and the levels of decision making (De Groot 1992, De Groot et al. 2002). 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 productivity in a sufficient number of agro-ecosystems worldwide. This means that biodiversity governance involves a multitude of actor groups that is quite diverse and heterogeneous (Daily 1999). 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 potential benefits. Some benefits naturally occur over large areas, while other goods, such as crops, livestock, fish, and medicines, are traded internationally, so consumer preferences can impact biodiversity over large distances without consumers realizing it (Vermeulen, 2004). Decision making regarding biodiversity – be it for the appropriation of goods and services, or in order to take measures for conservation – takes place at all levels of social organization. And, often decisions taken by one group of actors may lead to an impact on an entirely different group that takes its decisions with different interests in mind (Swanson, 2003).

Second, ecosystem goods and services vary in their properties, requiring different governance structures that take a range of transactions for their allocation and management into account (Dedeurwaerdere 2005). The conceptualization of natural resources in broad categories of different goods is not able to identify and distinguish the relevant transaction properties. The characterization of private goods, such as food, as being more adequately allocated through markets than public goods, such as climate regulation, cannot cover the relevant properties of a certain good or service from a particular perspective of use.

Third, institutions for biodiversity governance must thus include a variety of structures relating not primarily to goods and services, but rather more to the relevant properties of transaction, which are defined by the interest of the user. While the properties of the goods and services become obvious and palpable only when a transaction takes place, the anticipation of a user even without action taking place shapes the need for the governance structure to grasp conservation. The actor as a user with a certain interest in the good or service decides which property of transaction becomes analytically relevant. There are two more sides to the relevant properties of transaction in biodiversity management. First, even if we cannot observe an activity, it can imply a choice relevant for conservation and, equally, be shaped by actor interest. Second, the influence of the physical attributes of the resource and the process itself determine the transaction. Institutional diversity is not only important with respect to the multitude of scales of interaction and appropriation, but also with respect to a careful fitting of governance structures to the range of alternative transactions regarding biodiversity goods and services.

For the development of resource use-perspectives non-use values and ecosystem goods and services are relevant to the extent as they are considered by the actors. If they are not aware of them, they are exogenous to our approach, which of course does not mean that they are not relevant per se, simply they are not an active in the sense of "virulent" factor in our analysis. This is the case when the actor knows non-use values and ecosystem goods and services, honors them out of altruistic motives or believes in their intrinsic value and considers them in his decisions. There exists a trade-off between analytical rigor and the degree how to take into account complex interdependencies and feedback mechanisms. We distinguish between exogenous and dependent variables relevant for the actors' decision.

3. Transactions as the Unit of Analysis

It is important to be clear about the distinction between a transaction as a conceptual devise to support, on the one hand, movement of rights and, on the other hand, as an actual physical transfer of things. Transactions are closely liked to the interest and motivation of the actor: "Transactions are, not the exchange of commodities, but the alienation and acquisition, between individuals, of the rights of property and liberty created by society, which must therefore be negotiated between parties concerned before labor can produce, or consumers can consume, or commodities can physically be exchanged" (Commons, 1931: 652). In contrast, Williamson (2000) concentrates on the physical properties of goods, limiting transactions namely by specificity, frequency and uncertainty. These characteristics present obstacles to the realization of rights. The central analytical unit according to Williamson is the physical transaction, which has to be secured by contracts. The focus of Williamson on the physical transactions concentrates on the technologically

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separable interface (Beckmann, 2002). This prevents the analysis of other, alternative transactions, which are not necessarily observable, such as the alternative use of seed material as genetic information in the biotechnology industry. When a quantity of grain has been sold as seed, its genome is delivered simultaneously. Williamson developed his theory of transactions causing costs because of certain properties entailed by his example of the manufacturing industry; application to natural resources requires an extension. The resource biodiversity in this example physical grain – is able to reproduce itself and is, therefore, more difficult to control than a manufactured car.

We adopt the definition of transaction as the unit of observation in institutional analysis as proposed by Schmid (2004:10): If institutions are both formal and informal habits — including language, contract laws and constitutional rules — then, conceptually, a transaction is a cognitive understanding among people and is not to be confused with the physical movement of goods. The term captures the idea of interaction for whatever result as a part of institutions and a consequence of their interdependence. Schmid emphasizes that today's transactions are structured by both past and expected future interactions. Hagedorn (2008) argues for distinguishing physical transactions from institutionalized transactions: the former do cause material linkages and frictions, whereas the latter induce a change in social relationships from one actor's domain to another actor's domain, affecting individual rights and mutual obligations. Thus we understand a transaction to be a cognitive social relationship characterized by interdependence and interaction, as well as mutuality – be it for conflict or coherence – linking two activities with their respective attribute (Fig. 1).

While physical transactions appear to be identical, they differ on the level of property rights, which define relative opportunities (Schmid, 2004: 9). When selling certified seeds, the prohibition on using the grain again as seed material is not covered by the analysis of its physical properties alone. Here, we observe interdependencies of different uses on a property rights level. Instead of the economizing lens of Williamson's theory of contract, Schmid suggests a concern with the power issues concerning whose interests count if one or the other institution is put in place. Therefore, we propose an explicit perspective on use to capture the key concern of competition between different bundles of rights. In developing use-perspectives as an analytical tool, we seek to strike a balance between abstraction – a precondition for theorizing – and taking sufficiently into account the degree of complexity required for meaningful reflection on the factors determining the success or failure of institutions for sustainable biodiversity governance.

Identical physical exchanges (a grain is a grain), as depicted in Fig. 2, imply nevertheless different transactions and necessitate different governance structures, which are indicated by the arrows, which represent an institutional arrangement operating intentionally in the sense of pursuing certain actors interests. Common pool resources that are characterized by low feasibility of exclusion and high rivalry in consumption are often managed through reciprocal relationships. The properties of transaction for a good vary depending on the type and context of use or, in the words of Schmid (2004: 12), on the situation. Seed materials, for instance, are a type of genetic resource 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 growing 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 has been decoded and its value identified, it becomes an information resource that has the characteristics of a pure public good (Janssen, 1999; Swanson and Goeschl, 2000). These distinctions serve as entry points into the systematic analysis of use-perspectives (Figs. 3 and 4).

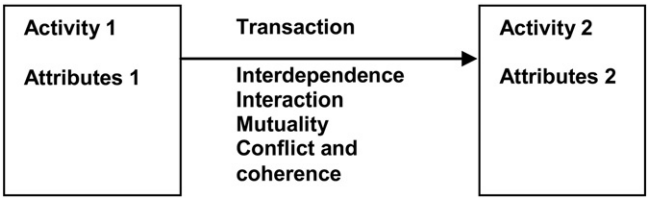

Fig. 1. Definition of a transaction.
Source: after Beckmann (2002).

4. Institutional Analysis of Biodiversity Governance

Institutional analysis of biodiversity governance requires first a careful conceptualization of the interface between human and economic systems. The unit of analysis defines the causal models that construct the relationship between explanatory variables. The main challenge is to find a way forward in restructuring and simplifying the maze of complexity outlined above. Instead of concentrating on single contextual factors, we suggest focusing on the properties of transactions and how they influence the interaction between actors and their interdependence.

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 sets of variables that could 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).

We will base our discussion on Hagedorn's framework for the analysis of *Institutions of Sustainability* (IoS) (Gatzweiler, 2005; Gatzweiler and Hagedorn, 2002; Hagedorn et al., 2002) and Ostrom's *Institutional Analysis and Development Approach* (IAD) (Ostrom, 1998a, 2005; Ostrom et al., 1994). Both of these frameworks emphasize the conceptual idea that the properties of transaction regarding natural resources, the attributes of actor groups managing those resources and the currently reigning institutional arrangements are the essential categories of explanatory variables for analysis of the development of such institutions.

4.1. Institutions of Sustainability Framework (IoS)

The units of analysis in Hagedorn et al.'s IoS framework are transactions that affect the natural environment and ecological systems. These transactions can be generating environmental problems through production and consumption activities, or reducing environmental problems through self organization (Hagedorn et al., 2002). The IoS framework was originally developed with a focus on agro-environmental coordination for sustainable resource management. Sustainability in this regard 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 ways they are interacting) (Gatzweiler and Hagedorn, 2002).

Due to its broad conceptual scope, we believe that this framework can be expanded to cover the whole range of interactions that relate to the appropriation of ecosystem services. A systemic question arises, however: How to analyze transactions which are not decomposable and are part of a complex ecosystem, which has not been designed by humans? Ecosystem functions providing goods and services like water regulation operate via only partly understood and, thus, barely institutionalized systems. Since many attributes of

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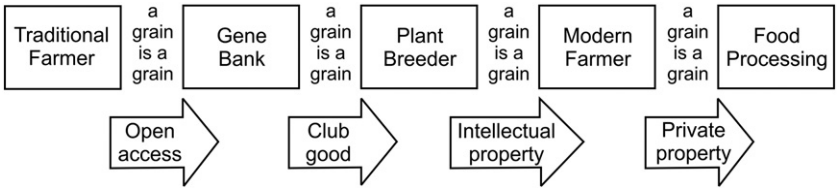

Fig. 2. BioComplexity: identical physical exchanges are different transactions which require other governance structures.

resources are not well known and their interrelations intransparent, transactions regarding these attributes pose a challenge to analytical efforts. However, one transaction will almost certainly influence a number of ecosystem functions, and its effects will differ for different ecosystem goods and services.

The IoS framework proposes four groups of determinants of institutional change: (1) features and implications of 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 over natural 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 gives consideration to the dynamic interdependence between changes among these four components that determine interactions between social and ecological systems. Nevertheless, the unit of analysis is still an observable transaction, though more properties have been incorporated to cover human–ecological interactions.

4.2. Institutional Analysis and Design Framework

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 specific action situations. An action situation is affected by three sets of exogenous variables: (1) the attributes of the biophysical world, (2) the attributes of the community within which the action arena is situated, and (3) the sets of rules used by participants to order their relationships. These categories contain a large number of potentially relevant variables and, thus, a sheer unlimited amount of combinations exists that may be relevant for explaining 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. Empirical research will show over time 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 guides 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 upon 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 level, collective choice rules are the outcome of constitutional choices, which are made on every jurisdictional level. Interactions between human and ecological systems are the result of operational choices. The rules that apply to operational choices at the human–ecosystem 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 structures, 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 (Ostrom 1998b, 2003; Gibson et al., 2000). The IAD approach is thus directly concerned with property rights related to the attributes of the resources and not only with observable transaction problems.

4.3. Missing Conceptual Models to Distinguish Transactions

The IAD and the IoS framework, compatible theories, and families of explanatory models provide tools for analyzing institutional arrangements for sustainable resource management at multiple scales and levels of analysis. Nevertheless, the frameworks do not provide a tool for reducing the complexity of human interactions and the diversity of human–ecosystem relationships in a systematic way in order to make cases comparable across contexts. The large number of potentially relevant factors and 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

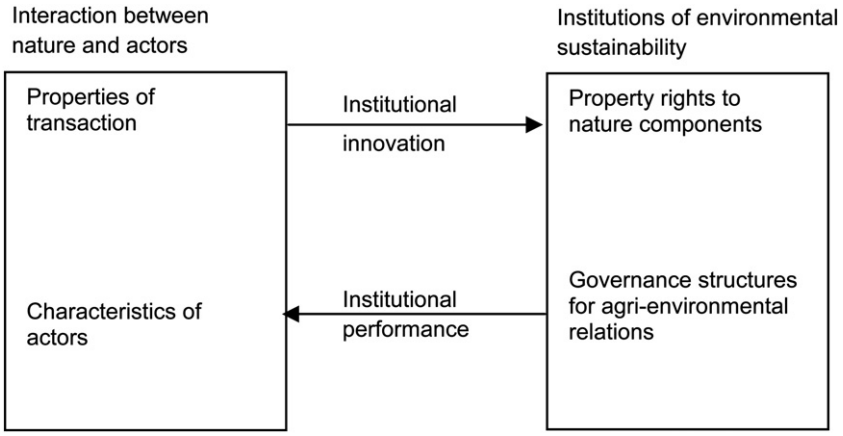

Fig. 3. The Institutions of Sustainability framework (IoS): the logic of institutional arrangements for agri-environmental coordination.
Source: Hagedorn et al. (2002:6)

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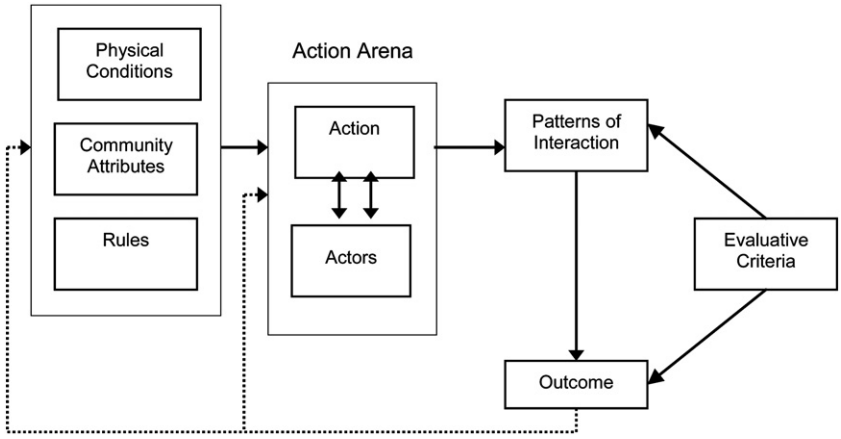

Fig. 4. Institutional Analysis and Development (IAD) Framework.
Source: Ostrom et al. (1994: 37).

no adequate theory or model available that allows incorporation of all new explanatory factors that may be revealed by empirical research.

Applying the IAD framework to support the development of more general explanations of institutions for natural resource management is anything but trivial. Ostrom's recommendation to build a family tree of closely related theories seems reasonable in light of the complexities that research on common pool resources 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 being more generally applicable, as Agrawal (2001) eloquently points out. Theories of collective action phenomena in biodiversity governance have little explanatory power beyond the specific empirical setting in which they were conducted, as relevant causal models are missing. What is thus needed is an adequate method of abstraction.

Based on the recognition of the dynamic interdependency between human and ecosystem interaction in the IoS framework, acknowledging the power of the IAD framework to derive context-specific explanations according to the different levels of choice, and considering Agrawal's critique of missing conceptual models, we propose the use-perspective approach as a means for enabling systematic analysis of choice properties in biodiversity management.

5. Resource Use-Perspectives

The uses of a resource by actors define the typical perspectives on its properties. The transactions imply interdependence and form the building blocks of the use-perspective approach, incorporating actors' particular interests in biodiversity. Institutions, proposes Vatn (2005), serve to protect the interests of certain actors: a stance that directs the focus of analysis onto (1) governance structures which serve to protect interests as expressed in property rights; (2) the motivations, aims and values of the actors involved; (3) and the need to control transactions. Choices regarding a good are motivated by the aims of actors, which might differ from and even be contradictory to each other. To finally provide for the governance of overlapping interests, we propose use-perspectives as a first step for analyzing the relevant factors which influence resource use.

Bromley calls institutions "choice sets from which individuals, firms, households and other decision making units choose courses of action" (1989: 39). A choice regarding which action to take is guided by an actor's interests. This understanding of the deliberate use of a resource is the starting point for developing use-perspectives. For the construction of stylised use-perspective models, we propose to connect the motivations of actors to the central analytical dimension. Starting from the interest in a resource, be it for food production, conservation or breeding, different properties move into the focus of analysis or become irrelevant. Based on these interest-selected properties of transactions, we propose the following procedure of abstraction for the construction of use-perspectives to account for the qualified relationship by interest between conceptually separate categories (Hagedorn, 2008:23):

- We select properties of transaction relevant from a certain use interest;
- We reduce complexity by linking a transaction into a conceptual chain of relationship;
- We construct a sequence of transactions relevant for a user;
- The first step in building a use-perspective identifies the conceptual link based on interest between the biophysical attributes of a resource and the properties of possible transactions;
- The second step in building a use-perspective draws the institutional link between the properties of possible transactions with governance modes; and
- In building stylised use-perspectives, we can analyze them for their interdependence.

Biophysical resource attributes and governance modes cause problems in terms of interdependence between actors, since one actor's choice regarding the use of a resource affects the choices available for others. Rival use by one agent precludes that by another. Non-rivalry enables several agents to use a resource, such as landscape amenity, simultaneously. However, non-rivalry creates an interdependence regarding whose preferences count, because the quantity and quality of goods subject to joint consumption cannot be individually provided (Paavola and Agner, 2005: 256). Multiple uses of resources can imply multiple and different interdependencies that have to be addressed by multiple, overlapping institutions. For example, a type of grain can be conceptualized as food, seed or genetic information. Differences in use of a physically identical resource generate institutional consequences. We suggest the use-perspective, because it describes this interdependence between different actor interests and undertake their analysis.

5.1. Identifying Relevant Attributes and Properties of Transactions

Paavola and Agner (2005) identify resource attributes and actor attributes as the main drivers of interdependence. The first step in approaching use-perspective analysis is to determine which biophysical attributes are relevant for a certain user. Williamson (1996) focuses on the attributes of uncertainty, frequency and asset specificity through

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bilateral dependencies, important for transactions in human-designed institutions. Hagedorn (2008) tackles the problem of adequate transaction attributes for institutional analysis involving natural systems. Biophysical attributes do influence transaction properties by the virtue of their material resource characteristics, but, as explained above, they are not the same as the cognitive conception of the properties of transaction. Properties of transactions as observed in the ecosystem include "jointness and absence of separability, coherence and complexibility, limited standardisability and calculability, dimensions of time and scale, predictability and irreversibility, spatial characteristics and mobility, adaptability and observability etc." (Hagedorn, 2008: 12). To improve the analytical capability to identify institutional structures for the governance of transaction properties, Hagedorn suggests an approach for identifying relevant transactions for ecological goods and services along a continuum of "atomistic-isolated" and "complex-interconnected" transactions, while attempting to identify reasons for the differences in properties.

5.2. Identifying Forms of Interdependence in Transactions

In a second step, we need to consider complex cases of multiple uses, which are likely to generate multiple or overlapping problems of interdependence. If different actors are using different aspects of a resource (e.g. grain as food, planting material or genetic information) different forms of interdependence can arise for each use. While food is rival and excludable, seed is medium rival and medium excludable and genetic information is non-rival and non-excludable. These different degrees of interdependence require different institutions, and since the resource is physically identical, these are likely to overlap. Therefore, we need a tool to analytically separate different uses in order to understand the governance institutions that arise from them.

Interdependencies arise out of many use dimensions. A use-perspective is a chain of essential transactions necessary to realize an actor's interests. Staying with the example of the physically identical grain, a use-perspective can be delimited for those transactions that mark the transfer of its genetic material. Contrary to the focus of Williamson, which is on the problems related to physical transaction, we are interested in the type of interdependencies that arise out of those transactions which are physically identical, but differ regarding the properties. Because of the many use dimensions of the grain, each actor thus acts as demander and a supplier of the resource. The eating of the grain as food or its planting as seed requires a stylisation of use-perspectives to identify the interdependence of causal relations and resulting challenges for biodiversity governance. Biodiversity management thus can be interpreted as consisting of a number of uses, each of which can be further broken down into sequential chains of transactions, linked by certain interest.

5.3. Defining Relationships Between Use and Interdependencies

In order to build a use-perspective, we need a very basic idea about the central defining relationships between the activities of an actor group and the governance problem at hand. Thus we want to underline that we do not make claims about causal relationships here, nor that single causal relationships exist. Rather there are likely to be multiple relationships among variables. A better understanding of those multiple relationships can improve institutional design in particular if a method for comparison with other cases were similar relationships can be identified. For example, the transactions carried out to maintain a portfolio of diversity in crops and varieties by numerous actors in traditional agricultural systems are now concentrated in modern agriculture in the hands of a few actors. In the traditional system, actors cultivate seed, grow food and exchange genetic material; the existing institutions around the core variables of collective action, namely reputation, trust and reciprocity (Padmanabhan, 2008), give an indication of problems of interdependence for these transactions. The same applies to the actors carrying out transactions for the sake of breeding and seed multiplication. Comparison of the use-perspectives of the traditional farmer and the breeder, which we undertake in Section **6**, may help to analyze the problem of interdependency.

A first step in building a use-perspective is to seek out indications of interdependence. Yet, we can only identify typical requirements for institutional arrangements, not the arrangements themselves, because they depend on the actor characteristics and the political context. When building a model of a certain use-perspective, each link of the chain needs to be tested for competing uses, beginning with the identification of a potential transaction problem, for example the future availability of genetic resources, that may affect a user's interest. In a second step, we investigate whether this problem arises from multiple uses of the resource. Third, we ask which uses have an impact on the transaction and can lead to reductions in biodiversity, identifying different uses according to how they are driven by specific actor interests, such as traditional and modern farming, plant breeding, conservation and many others. Fourth, we need to define the biophysical attributes of each use-perspective and the transactions that characterize them. The conceptual challenge is to consider the transactions within one use-perspective and make them comparable across use-perspectives. This analytical task is prompted by the need for multiple and overlapping institutional arrangements for the different uses of a single resource.

We suggest that the reduction of complexity can be attained through the stylization of common resource use-perspectives regarding various aspects of ecosystem goods and services. Resource use-perspectives could serve as an 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 for common human–ecosystem interactions that is general enough to allow for comparison along the fundamental characteristics of a certain type of resource use, while also being flexible enough to capture the variance that we can expect when analyzing across different settings.

A resource use-perspective evolves around the discovery of the cognitive properties of a transaction, as analytically separate and marked off from its physical ones. The biophysical characteristics of the natural resource have certain attributes and are used according to certain interests. And in this respect these attributes do influence the properties of transactions as cognitive entities, caused by interdependence, interaction, mutuality and conflict respectively coherence. Only the conjunction with the use and its relevant attributes allows us to identify an arising governance problem. Thus, a use-perspective is in one sense an abstraction for identifying necessities for institutional coordination.

The relationship between variables is shaped by the interest, which leads to intentional action, observable in the transaction, made possible by the institutional arrangements. Thus we are particular in depicting the link between the biophysical characteristic of the resource and its use of a certain attribute as a spatial arrow, which encompasses feedback mechanisms. These possible loops are represented in Figs. 5–8 by the mutual influence of biophysical and social attribute of the resource within the institutional arrangement. In this space multiple relations among variables exist and their interdependency drives the co-evolution between ecological and social systems.

A resource-use-perspective is defined by a group or series of transactions that typically occur simultaneously, or in close conjunction with each other, and involves at least one identical actor or actor group (e.g. commercial farmers who buy grain as seed and sell grain as food). There are two reasons for clustering possible transactions. First, they are only comprehensible in connection with the resource attributes that become apparent through its being used and, second, similar transactions need to be pooled to craft adequate governance structures and reduce costs through effects of scale.

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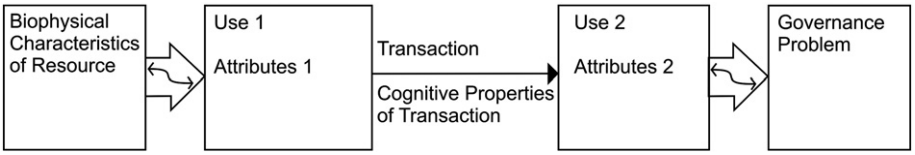

Fig. 5. A resource use-perspective.

Nevertheless, these specific governance structures may interfere with other structures organizing other transactions. To stay with our example, it is reasonable to assume that a commercial farmer would not buy seed if he did not have the expectation of selling its produce. These interdependencies complicate or even prohibit the analysis of transactions in isolation. The grain a farmer buys for use as seed and that which she 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 a food source. If so, the farmer faces a dilemma. She can buy high quality seed and accept the likelihood of a lower price for her produce, or she 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 may prefer?

Furthermore, we need to analytically deal with the implicit links between transactions. This is to say, 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 possible transaction, Y. The actor already has Y in mind when performing X, for example non-use values. Thus, there is an implicit link between two transactions that would be ignored if we were to analyze each likely transaction or alternative property in isolation. While it seems fairly easy to include the concern about a hard grain shell in an explanation of a farmer's preferences, things quickly become more complicated if the attributes affecting a transaction are more subtle.

6. How to Build a Resource Use-Perspective

In the following we build a set of resource use-perspectives based upon the example we have used for illustration so far. The interest of a commercial farmer shall serve as our case: in grain as seed as a first use and in marketable food as a second. The traditional farmer use-perspective and the breeder use-perspective are also briefly outlined.

The attribute of intransparency of the biophysical resource grain shapes the relevant properties of the transaction. 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 the limitation that the genotype of a plant – its genetic potential – is not directly observable. Even in full maturity, the phenotype – the mature 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 regarding seed and planting materials and, subsequently, to a considerable level of risk for the buyer. The transaction comprises the interaction between grain as seed and grain as food; different interests in different biophysical attributes are clouded by the property of transaction intransparency.

The two activities of sowing and selling grain as food are interdependent through the transaction. For the second activity or use, the selling of grain as food, many of the productive properties of a variety, such as pathogen resistance or adaptability to certain environmental stresses are irrelevant to the grain consumer. Nevertheless, some quality attributes may still be affected by a transparency problem. Nutrient composition, vitamin content 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, a market regulation requires the farmer to provide detailed information about the grain's quality attributes, as for certifications, he will have to ensure that the seed supplier provides reliable and complete information about these attributes when he is buying the seed. The first use (seed grain) is affected by the governance structure regulating the second (food grain).

In accord with Commons (1931), we consider transactions not as the exchange of commodities, but the alienation and acquisition of the rights of property and liberty provided by institutions, which exist before any physical transfer can take place. 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 concerning one transaction, but also the interdependencies between various uses that are logically linked. Our example — taking Fig. 6 as a simplified model of the commercial farming perspective – consists of two activities (buying seed and selling food grains): a transaction and a governance structure.

We can make a number of very general conjectures about the institutional arrangements we would expect to find for the governance 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 channels of third-party enforcement), such as with certifications.

One might argue that these are the fundamental elements of any market transaction; however, our objective at this stage is to display how we can link a conjecture about institutional arrangements to an observable attribute of the resource via a postulated relationship driven by interest. In this case, the causality chain would be as follows: (1) incomplete observability of a plant's genotype in the phenotype leads to a problem of decreased transparency; (2) low transparency creates a problem of asymmetric information and increases risk for the buyer. Because of the conceptual relationship between transparency, information and risk, we postulate that (3) there

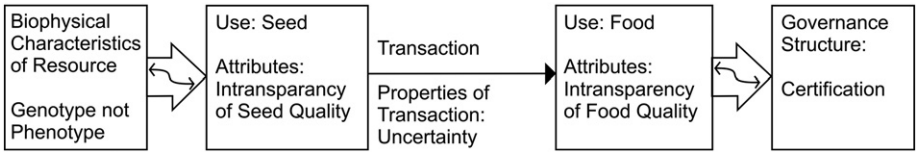

Fig. 6. The commercial farmer use-perspective.

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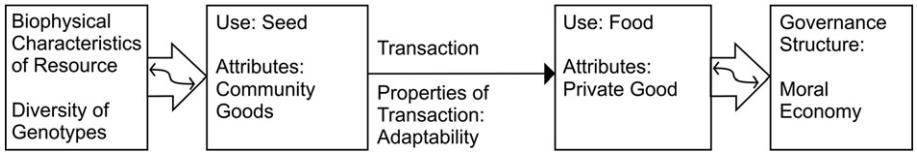

Fig. 7. The traditional farmer use-perspective.

is likely to be a mechanism that reduces risk for the buyer by means of an obligation to transfer information. Thus, governance structures affect the institutions regulating this kind of transaction.

In the selection of models, we need to define attributes and interests resulting in certain uses. Attributes influence transaction properties, but the two are not the same. While biophysical attributes do characterize the resource and thus influence transaction properties, the latter are the conceptual expression of the cognitive dimension of (mis)understanding resulting from users interests. The models thus describe the links between attributes and transaction properties; in turn, actual transactions determine which attributes are relevant. A well defined resource-use-perspective allows us to identify similarities among the many properties of transactions. This pool of similar or interdependent properties regarding transactions reveals sets of rules and governance structures. With this aim in mind, it should be possible to develop a research design that allows a meaningful comparison of different use-perspectives and the effects of natural attributes on institutional arrangements.

For selecting the explanatory variables of the attributes, we propose the merging of conceptual models of theoretical explanation with existing empirical knowledge. Bundling transactions into resource use-perspectives allows us to picture variables influencing a transaction by using the selection criteria of relevance and significance.[1] The relevance criterion in the selection of attributes seeks to determine the conceptual model appropriate to a theoretical explanation. Conceptual models can be derived through consistent deduction from logical linkages and relations, such as explanations based on natural sciences for biophysical attributes, as well as theories used in the social sciences. Meanwhile, the significance criterion brings already existing knowledge on resource uses into the analysis. We know from empirical research that certain attributes do have a strong impact on the properties of a transaction and the institutional responses for addressing governance problems arising out of these properties (Agrawal, 2001). This knowledge can and should be used to refine future research and analysis.

In the following we want to discuss two more examples of resource use-perspectives, namely the traditional farmer use-perspective and the breeder use-perspective, less in-depth due to limitations of space. We want to illustrate the ways in which a use-perspective is build on the following three questions regarding an actor's involvement with the resource in question:

1. What two uses of a resource become interdependent through a transaction? A use is the consideration of a certain attribute guided by an interest.
2. How do interests shape the framing of the attribute? The properties of transaction are a conceptual expression of the cognitive dimension.
3. What institutional environment can we conjecture? This encompasses the observable attributes and their relationship driven by interests.

Building on a large body of significant knowledge (see, for instance, Brush, 2000; Louette et al., 1997; Smale et al., 2004) and the relevance of logical sequences, we define the use-perspective of traditional farmers. The traditional farmer is interested in maintaining a broad crop portfolio to equally achieve yield stability, quality and maximum. 1.) Her interest is to produce food. She invests in a dynamic agro-ecosystem to reduce risk, for which she needs a diversity of genotypes in seeds. 2.) Her interest is in a seed portfolio maintained as a local available and adapted community good to provide her with adaptability. The varieties of genotypes to choose from serve her risk-diversification strategies (Padmanabhan, 2011). 3.) The institutional arrangement expected is able to support reciprocal exchanges, which moves information on the seed quality as food and as a central item in a complex farming strategy. To ensure the flow and safeguarding of this information, a moral economy is the governance structure to be expected (Padmanabhan, 2008). This use-perspective of traditional farmers would then allow the targeting of certain sources of variance in the selection of case study sites for comparative analysis across countries and cultures.

The breeder use-perspective captures transactions between ex-situ conservation in a gene bank and the private enterprise of a breeder. 1.) The breeder wants to identify valuable traits in seeds from the public domain for further selection activities. He wants to use this characteristic to improve the seed material as his private product. 2.) He is on the one hand interested to obtain the results of former breeding and selection activities (Smale, 1998), now stored in genebanks under diminishing viability; at the same time there emerges a rivalry to protect the value addition of the self-reproducing grain. 3.) Thus we expect an institutional environment to emerge, that takes the multi-dimensionality of the seed into account by granting institutional exclusion mechanisms via an intellectual property rights regime, to distinguish the identification from the common pool.

It reveals a conflict over differing property rights attributes, which are governed by intellectual property rights. Nevertheless, the governance structure has to deal with the biophysical phenomenon of sinking seed viability, meaning the diminishing capacity of stored seed to germinate, creating a need for constant reproduction. With the transaction from the gene bank to the breeder the character of the good changes from a (inter)national public good to a private commodity governed by intellectual property rights. A careful stylization of the breeders use-perspective may allow for international comparative studies.

7. Conclusion: Biophysical Attributes Link Governance Structures via Transactions

The examples of resource use-perspectives (Figs. 6–8) closing this paper illustrate that, in order to establish the conceptual relationships that define particular resource use-perspectives, we need to differentiate the biophysical attributes of the ecosystem good or service from the properties of the transactions related to it. Attributes influence transaction properties, but the two are not the same. Once we have established this distinction, we can describe the relationship through the link between the biophysical attributes and the properties of possible transactions, on the one hand, and between the properties of the transactions and the governance problems related to them, on the other.[2]

[1] See Hagedorn (2008) for conceptualizing the development of adequate attributes for natural goods and services.

[2] In the case of the commercial farmer (Fig. 6), 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.

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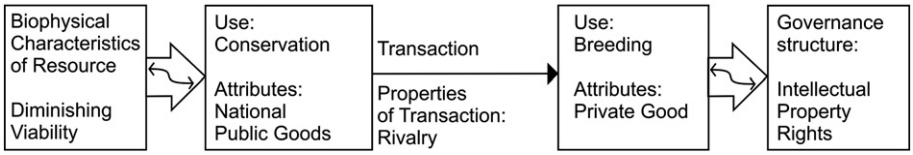

Fig. 8. The breeder use-perspective.

For building use-perspectives we have relied on a stylization of use types, based on the making of necessary assumptions. In the above example of the commercial farmer (Fig. 5), we have argued that low transparency of seed transactions is a consequence of the natural attribute that seed and planting materials do not readily display the genotype of a plant. This is only one factor that influences the transparency of this transaction. Biodiversity governance is, nevertheless, characterized by a multitude of interacting factors, and their influence on transactions resembles a complex web, as indicated in the arrows depicting institutional arrangements with feedback loops. Furthermore, governance problems do not occur in separation from transactions. If we observe a large number of similar transactions, aggregation problems have to be faced. The aggregation of transactions with similar attributes under one governance structure takes place in a nested system of governance units. Problems of this kind result in the pooling of requirements, thus leading to the necessity of creating governance structures, which themselves generate regulation on a higher level, causing an umbrella of further governance structures on higher levels. From a logical point of view, the higher systems are the product of the lower ones. The result of such an analysis would take into consideration the institutional context via the problems of aggregation and the resulting attempts at finding an adequate governance solution.

At this point, the resource-use-perspective approach is still at the stage of being a thought experiment, and further work is needed to develop a method that can be operational for research. Part of this work should consist of testing whether the procedure we have depicted above can be fruitfully applied to other problem settings. The representation of the traditional farmer-use-perspective and the breeder use-perspective could for instance yield interesting insights into research on new forms of cooperation between farmers and plant breeders to enhance conservation and development of genetic resources for agriculture.

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 conceptual models that display the logic of interaction with the ecological system of different user groups. Once this logic is made explicit, we can test whether decisions taken at higher levels take it into account and conform to it or ignore it. Similarly, tests could be conceived regarding the compatibility of suggested approaches with the logic of resource use typical of a certain actor group.

These applications are but hypothetical at the moment. Further work will have to explore the idea of resource use-perspectives. So far, use-perspectives include conceptual models that display the logic of interaction with ecological goods and services derived from natural resources typical of different user groups. They allow the testing of the compatibility of the logic of resource use of a certain user group with the logics of other uses. Finally, use-perspectives support efforts to identify constraints of, while highlighting the need for institutional change.

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References

Agrawal, A., 2001. Common Property Institutions and Sustainable Governance of Resources. World Development 29 (10), 1649–1672.
Arrow, K., 1951. Social Choice and Individual Values. Wiley and Sons, New York.
Beckmann, V., 2002. Transaction Cost and Environmental Economics—Towards a New Approach. Paper presented at the "Institutional Analysis and Development Seminar". Workshop in Political Theory and Policy Analysis, Indiana University, Bloomington, December 10th, 2002.
Bromley, D., 1989. Economic Interests and Institutions: The Conceptual Foundations of Public Policy. Blackwell, Oxford.
Brush, S.B., 2000. Genes in the Field, On-Farm Conservation of Crop Diversity. Lewis publishers, New York.
Commons, J., 1931. Institutional Economics. American Economic Review 21, 648–657.
Daily, G., 1999. Developing a scientific basis for managing Earth's life support systems. Conservation Ecology 3 (2), 14.
De Groot, R., 1992. Functions of Nature: Evaluation of Nature in Environmental Planning, Management and Decision Making. Wolters-Noordhoff, Groningen.
De Groot, R.S., Wilson, M.A., Boumans, R.M.J., 2002. A typology for the classification, description and valuation of ecosystem functions, goods and services. Ecological Economics 41 (3), 393–408.
Dedeurwaerdere, T., 2005. From bioprospecting to reflexive governance. Ecological Economics 53 (4), 473–491.
Gatzweiler, F., 2005. Institutionalising biodiversity conservation—the case of Ethiopian coffee forests. Conservation and Society 3 (1), 201–223.
Gatzweiler, F., Hagedorn, K., 2002. The evolution of institutions in transition. International Journal of Agricultural Resources, Governance and Ecology 2 (1), 37–58.
Gibson, C.C., Ostrom, E., Ahn, T.K., 2000. The concept of scale and the human dimensions of global change: a survey. Ecological Economics 32 (2), 217–239.
Hagedorn, K., 2008. Particular Requirements for Institutional Analysis in Nature-Related Sectors. Key note lecture prepared for the XII Congress of the European Association of Agricultural Economists, Ghent, Belgium, August 26–29, 2008.
Hagedorn, K., Arzt, K., Peters, U., 2002. Institutional Arrangements for Environmental Co-operatives: A Conceptual Framework. In: Hagdorn, K. (Ed.), Environmental Co-operation and Institutional Change: Theories and Policies for European Agriculture. Edward Elgar, Cheltenham.
Heal, G.M., 1999. Biodiversity as Commodity. Columbia University, Columbia.
Heal, G., 2004. Economics of biodiversity: an introduction. Resource and Energy Economics 26 (2), 105–114.
Janssen, J., 1999. Property Rights on Genetic Resources: Economic Issues. Global Environmental Change-Human and Policy Dimensions 9 (4), 313–321.
Jungcurt, S., 2008. Institutional Interplay in International Environmental Governance. Policy Interdependence and Strategic Interaction in the Regime Complex on Plant Genetic Resources for Food and Agriculture. : ICAR, 30. Shaker, Aachen.
Louette, D., Charrier, A., Berthaud, J., 1997. In situ conservation of maize in Mexico: genetic diversity and maize seed management in a traditional community. Economic Botany 51 (1), 20–38.
Millennium Ecosystem Assessment (Ed.), 2005. Ecosystems and Human Well-being: Biodiversity Synthesis. World Resources Institute, Washington DC.
North, D.C., 1990. Institutions, Institutional Change, and Economic Performance. Cambridge University Press, New York.
Ostrom, E., 1998a. The Institutional Analysis and Development Approach. In: Loehman, E.T., Kilgour, D.M. (Eds.), Designing Institutions for Environmental and Resource Management. Edward Elgar, Cheltenham, pp. 68–89.

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Ostrom, E., 1998b. Scales, Polycentricity and Incentives: Designing Complexity to Govern Complexity. In: Guruswamy, L.D., McNeely, J.A. (Eds.), Protection of Global Biodiversity: Converging Strategies. Duke University Press, North Carolina, pp. 149–167.
Ostrom, E., 1990. Governing the Commons: The Evolution of Institutions for Collective Action. Cambridge University Press, Cambridge.
Ostrom, E., 2003. How types of goods and property rights jointly affect collective action. Journal of Theoretical Politics 15 (3), 239–270.
Ostrom, E., 2005. Understanding Institutional Diversity. Princeton University Press, Princeton.
Ostrom, E., Gardener, R., Walker, J., 1994. Institutional Analysis and Common Pool Resources. In: Ostrom, E., Gardener, R., Walker, J. (Eds.), Rules. : Games and Common Pool Resources. University of Michigan Press, Michigan, pp. 23–50.
Ostrom, E., Burger, J., Field, C.B., Norgaard, R.B., Policansky, D., 1999. Revisiting the commons: local lessons, global challenges. Science 284 (5412), 278–282.
Paavola, J., Agner, W.N., 2005. Institutional ecological economics. Ecological Economics 53, 353–368.
Padmanabhan, M., 2008. Collective action in plant genetic resources management: gendered rules of reputation, trust and reciprocity in Kerala, India. Journal of International Development 20 (1), 83–97.
Padmanabhan, M., 2011. Women and men as conservers, users and managers. a feminist social–ecological approach. Journal of Socio-Economics 40, 968–976.
Schmid, A., 2004. Conflict and Cooperation. Institutional and Behavioral Economics. Blackwell, Oxford.
Smale, M., 1998. Farmers Gene Banks and Crop Breeding: Economic Analyses of Wheat, Maize and Rice. Kluwer Academic Publishers, Boston, Massachusetts.
Smale, M., Bellon, M.R., Jarvis, D., Sthapit, B., 2004. Economic Concepts for Designing Policies to Conserve Crop Genetic Resources on Farms. Genetic Resources and Crop Evolution 51 (2), 121–135.
Swanson, T., 2003. Introduction to property rights and biodiversity conservation: convergence or conflict? Land Economics 79 (4), 457–459.
Swanson, T., Goeschl, T., 2000. Property rights issues involving plant genetic resources: implications of owner-ship for economic efficiency. Ecological Economics 32 (1), 75–92.
Vatn, A., 2005. Institutions and the Environment. Edward Elgar, Cheltenham.
Vermeulen, S., 2004. Biodiversity Planning: Why and How Should Local Opinions Matter? Gatekeeper Series, 115. International Institute for Environment and Development, London.
Williamson, O., 1996. The Mechanisms of Governance. Oxford University Press, Oxford.
Williamson, O., 2000. The new institutional economics: taking stock, looking ahead. Journal of Economic Literature 38, 596–613.

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