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Abstract

RESILIENCE AND THE CO-EVOLUTION OF ECOSYSTEMS AND INSTITUTIONS

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Resilience is the ability of a system to cope with change without collapsing. It is the capacity to absorb external perturbations, by actively adapting to an ever changing environment. Reduction in resilience means that vulnerability increases, with the risk that the whole system flips from one equilibrium state to another. Such flips are often a consequence of the misuse of the environment and the inertia of institutions to change. Smaller unpredictable perturbations that previously could be handled turn into major crises when extreme events intersect with internally generated vulnerability due to loss of resilience. To avoid such situations there is a need for institutions with the ability to respond to and manage environmental feedbacks, institutions that can cope with unpredictable perturbations before they accumulate and challenge the existence of the whole social-ecological system. This implies that it is not enough to only understand the institution in question. The dynamics of the ecosystems that form the biophysical precondition for the existence of the institution need to be taken into account as well. This study focuses on the linked social-ecological system, and its dynamic interrelationships. We regard it as one system with its social and ecological components co-evolving over time. It is in this context that we study traditional and newly-emergent social-ecological systems. We are analyzing 1) how the local social system has adapted to and developed a knowledge system for dealing with the dynamics of the ecosystem(s) including the resources and services that it generates, 2) specifically, how the local system maintains ecosystem resilience in the face of perturbations, and 3) those combinations of property rights arrangements, institutions, and knowledge systems which accomplish the above successfully. Examples will be presented from the Cree Indians of the Canadian eastern subartic and their resource management, and pastoral herders and rangeland management in semi-arid Africa.

IASCP PRESENTATION AND PAPER ARE BASED ON
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MECHANISMS WHICH LINK PROPERTY RIGHTS TO ECOLOGICAL SYSTEMS[1]

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ABSTRACT

This chapter addresses local commons and their interrelationships with environmental resources and ecosystems. We discuss the commons and property rights, and provide some major lessons from the common property literature with regard to the interface between ecological and social systems. Next a systems view of social and ecological interactions is presented, stressing the need for active social adaptations to environmental feedbacks. Such adaptations are discussed in relation to traditional ecological knowledge. Through a number of case studies we are searching for the mechanisms guiding ecological adaptation of human groups to their diverse environments. Each case study is designed to contribute to a social-ecological framework presented here, which tries to synthesize the following: What lessons can be learned to assist in the designing of more sustainable resource management systems? How can adaptiveness and resilience be built into institutions so that they are capable of responding to the processes that contribute to the resilience of ecosystems? Are there similarities, general patterns, principles, and policy recommendations that can be drawn from the case studies? Understanding the mechanisms guiding sustainability of the combined social-ecological systems could help design more effective and adaptive management for ecological systems in general.

1. INTRODUCTION

The property rights issue of concern in this paper is mainly in the domain of a class of resources which are neither pure private goods or pure public goods. Thus, the scope does not include industries, services, most agricultural land, mineral resources, and state owned reserves and parks, but includes common-property (or common-pool) resources. Further, in the realm of commons, the focus area of this paper is local commons which is the major literature base on the interface of ecological and social systems.

The paper presents some perspectives on the linkages between social and ecological systems, and cover some aspects of the state of knowledge and search for social mechanisms behind sustainable uses of ecosystems.

There are four points in the paper. First, we know enough to improve on Hardin's conceptual model of the commons which so dominated the thinking of some scholars and resource managers that it was widely assumed that individuals using resources jointly were helpless to change the incentives they faced. Second, it is argued that the focus on property rights necessarily expands the scope of ecological and economic analysis to include the social/institutional/cultural dimension. Elsewhere, we have characterized this linkage as natural capital - cultural capital - human-made capital interaction (Berkes and Folke 1994). Third, traditional ecological knowledge represents a summation of millenia of ecological adaptation of the social/institutional/cultural dimension to its diverse environments. This knowledge is important for its potential to help design more effective and adaptive management for ecological systems in general. Fourth, we search for the mechanisms that improve the use of environmental resources and ecosystems, and increase the well-being and sustainability of the integrated social-ecological system.

2. THE COMMONS AND PROPERTY RIGHTS

By far the best known of the various formulations of the commons dilemma is the "tragedy of the commons", as used by Hardin as a parable to explain overgrazing in a hypothetical Medieval English commons. Each herdsman seeking individual gain wants to increase the size of his herd. But the commons is finite, and sooner or later the total number of cattle will exceed the carrying capacity of the land. But it is in the rational self-interest of each herdsman to keep adding animals: his personal gain from adding one more animal (+1) outweighs his personal loss (a fraction of -1), from the damage done to the commons. However, since all herdsmen use the same logic, eventually they all lose. Hence, the overexploitation of the commons is an inevitable result, and a tragedy in the sense of ancient Greek tragedies according to Hardin, in which the characters know that the disaster is coming but are unable to do anything about it.

Hardin's (1968, p. 1244) notion that "freedom in the commons brings ruin to all" was taken quite literally, and accorded by some the status of scientific law. But many scholars knew that the case study would not hold up to historical scrutiny and that the generalization about commons was inappropriate (Feeny et al. 1990). Improving upon Hardin's analysis of commons required, among others, an organizing framework of property rights regimes applicable to common property resources.

Hardin's seminal "tragedy of the commons", with its group of Medieval English herders locked in a downward spiral of resource degradation is a powerful metaphor for the consequences of the lack of property rights on the commons. But it is not a very good characterization of what really happens in many commons cases. Much of the commons literature suggests instead a "bucket brigade" metaphor. Given a resource management problem, a group of people will often organize themselves in a way that is similar to the formation of a bucket brigade to put out the fire in a rural community.

Figure 1 attempts to summarize the two metaphors as simple feedback models of an integrated natural-social system. The major differences between the two models are in the stabilizing feedback loops that connect the social system and the natural system. For common property resource use to be sustainable, there should be feedback informing the management institution about the state of the resource; there should also be feedback between the regime and the resource user. When these stabilizing feedbacks are absent (or assumed away, as done by Hardin) then one is left with a runaway positive feedback loop, and this integrated social-natural system cannot be sustainable in the long-term.

Such an interpretation is consistent with the literature. Much of the common property literature is notable in its attempt to study the interface between natural and social systems, and to establish a dialogue between natural resource specialists and social science specialists. Some of this literature is captured and interpreted in a series of fairly recent volumes by e.g. McCay and Acheson (1987), Berkes (1989), Ostrom (1990) and Bromley (1992).

Some of the major lessons from the common property literature with regard to the inteface between ecological and social systems, may be summarized as follows:

- resource users are often not a collection of independent individuals but tend to be connected through formal or informal institutions, and they are capable of communication and altering incentive structures,
- from a historical perspective, the use of common-property resources has rarely been a free-for-all (open access), except for short periods of rapid change,
- there often is a resource management regime, which may be a government regime but more often a local, informal regime, that regulates the way in which resources are used,
- in the case of local, informal regimes, the resource use behaviour of individuals is often mediated by a variety of social controls or social sanctions,
- the presence of a "community" is an important (e.g. Taylor 1982) but not a sufficient condition to solve the commons problem (Ostrom 1992),
- many of the principles that may be derived from local commons cases are applicable to, or have their parallels with international commons cases (Keohane et al. 1992),
- there are design principles (Ostrom 1990, 1992 identifies eights) which may be used as predictors of success for common property institutions, and

- there often are numerous feedback loops in most natural-social systems involved in the use of common property.

Here, we are interested in such social-ecological feedbacks.

3. A SYSTEMS VIEW OF SOCIAL AND ECOLOGICAL INTERACTIONS

In general terms, property rights institutions are part of the "cultural capital" by which societies convert "natural capital", that is, resources and ecological services, into "human-made capital" or the produced means of production. We have used the term cultural capital (Berkes and Folke 1992, 1994) to refer to factors that provide human societies with the means and adaptations to deal with the natural environment and to actively modify it. As we see it, cultural capital includes what others have called social capital and institutional capital. It also includes how people view the natural world, values and ethics, including religion, and culturally transmitted knowledge of the environment, indigenous knowledge.

Figure 2 presents a view of how the three kinds of capital may be interrelated. Natural capital is the basis for cultural capital. For example, property rights institutions are closely related to the characteristics of the resources used by that society (Geertz 1963). In turn, attitudes and practices of a society regulates the exploitation of its natural capital (Freeman et al. 1991; Posey and Balee 1989). Thus, human-made capital is generated jointly by natural and cultural capital; the use of natural capital under a particular set of institutions, attitudes and technology produces human-made capital. Human-made capital may, in turn, alter cultural capital; for example, technologies may mask a society's dependence on natural capital and provide a false sense of control over nature. Thus, cultural capital is closely linked to how natural capital will be used; technologies reflect cultural values, world view and institutions (Gadgil et al. 1993; Warren et al. 1994).

How would the three capitals interact under different property rights regimes?

The short answer is that we do not know. There is as of yet no well developed literature in this area. However, some tentative observations/speculations may be offered:
- ways of enhancing the turnover of information within the larger social-ecological system will enhance the performance of natural resource systems,
- new adaptations or a constant elaboration of cultural capital will be necessary to keep up with changes in human-made capital,
- the sustainable use of natural capital will be facilitated by those property rights regimes capable of responding to feedbacks from natural capital, and
- property rights regimes must be flexible, adaptive, diverse and capable of self-renewal.

The introduction of the notion of cultural capital, with all the informal and intangible dimensions that it embodies, no doubt complicates the more manageable ecology-economics dichotomy. But it also serves to highlight systems many of which are informal and thus largely "invisible" to conventional analyses. These informal systems (such as local common-property institutions and traditional knowledge systems) tend to be found more in the Third World than the Industrial West, more in rural than in urban areas, and in many cases, more in female-dominated than in male-dominated activities. These are not areas in which conventional analyses are known to be strong.

In contrast to the detailed studies of institutions and economic performance, there seem to be no detailed studies or syntheses that focus on the performance of the ecological system itself under different property rights regimes. What is available, however, is a rich literature on local and traditional management systems.

4. TRADITIONAL ECOLOGICAL KNOWLEDGE AND RESOURCE MANAGEMENT

This section is about the role of traditional ecological knowledge for sustainable use of resources and ecosystems. Traditional knowledge represents a summation of millenia of ecological adaptation of human groups to their diverse environments, and is important not just for its own sake but for its potential to help design more effective and adaptive management for ecological systems in general.

The term indigenous knowledge (IK) is broadly defined as the local knowledge held by indigenous peoples or local knowledge unique to a given culture or society (see also Indigenous Knowledge and Development Monitor 1992), and is used here interchangably with traditional knowledge. More specifically, we use the term traditional ecological knowledge (TEK) as a subset of IK, defined here as a cumulative body of knowledge and beliefs, handed down through generations by cultural transmission, about the relationship of living beings (including humans) with one another and with their environment (Berkes 1993). Indigenous knowledge or TEK is an attribute of societies with historical continuity in resource use practices; by and large, these are non-industrial societies, many of them indigenous or tribal (Warren et al. 1994).

Traditional knowledge is important for its own sake and for its social/cultural value. But, it is also significant for a number of practical reasons. The following list is adapted from the IUCN Programme on Traditional Knowledge for Conservation (IUCN 1986) by Berkes (1993):

(a) TEK offers new biological knowledge and ecological insights,

(b) Some TEK systems provide models for sustainable resource management,

(c) TEK is relevant for protected areas and conservation education,

(d) The use of TEK is often crucial for development planning, and

(e) TEK may be used in environmental impact assessment.

There are many similarities between TEK and scientific knowledge. Both are attempts to make sense of the world, to render it comprehensible to the human mind. Both are based on observations and on generalizations deriving from those observations. Many parallels can be drawn between these two kinds of knowledge. For example, Gadgil and Berkes (1991) suggested that a number of "rules of thumb" developed by ancient resource managers and enforced by social means, parallel rules that may be derived from the science of ecology, and may function in much the same ways.

There are, however, also some notable differences between the two kinds of knowledge. In particular, indigenous knowledge differs from scientific knowledge in its:

- restricted geographical scale of observations,

- reliance on mainly qualitative (rather than quantitative) information,

- lack of a built-in drive to accumulate more and more facts,

- slower speed in the accumulation of facts,

- more reliance on trial-and-error, rather than on systematic experimentation,

- limited scope for the verification of predictions, and

- lack of interest in general principles or theory-building.

As well, a number of additional characteristics of indigenous knowledge systems are suggested by detailed studies of traditional ecological knowledge in indigenous cultures and tribal peoples (see references in Berkes et al. 1994). A number of generalizations can be offered on the basis of these studies. It appears that indigenous knowledge differs from scientific knowledge in being moral, ethically-based, spiritual, intuitive and holistic; it has a large social context. Social relations are not separated from relations between humans and non-human entities. The individual self-identity is not distinct from the surrounding world. There often is no separation of mind and matter. Traditional knowledge is an integrated system of knowledge, practice *and* beliefs.

A major strength of indigenous knowledge lies in the long time-series of observations on particular local and regional ecosystems. That is, indigenous knowledge is based on diachronic data (long-term series), as opposed to synchronic data (short time-series over a large area) characteristically produced by Western science. Thus, the two kinds of data may be compatible and complementary. There is great potential value in historical series of observations about particular areas, based on cultural transmission of knowledge from generation to generation, provided that the particular environment has not in the meantime been drastically perturbed.

Western science of resource management has until recently emphasized exploitation efficiency, in terms of physical and monetary yields, rather than sustainability in resource use. Resource harvesting proceeds most effectively with simplified systems, as in agriculture and forestry, and on the basis of understanding of only part of the larger system. Gadgil and Berkes (1991) and McNeely (1991), among others, have pointed out that scientific management has its roots in the utilitarian and exploitive world view that assumes that humans have dominion over nature, and is best geared for the efficient utilization of resources as if they were limitless. The replacement of a diversity of local systems by a monolithic scientific management vision, has in most cases not led to sustainable outcomes. There are many examples of natural resource depletion or degradation due to the replacement of locally adapted, subtle and complex common-property systems, by government management or private property, especially in the Third World (McCay and Acheson 1987; Berkes 1989).

By contrast, managing for sustainability requires an understanding of the system in all its complexity. The relevance of indigenous knowledge for the sustainable management of tropical forest, dryland, mountain and arctic/subarctic ecosystems is recognized not only by a few specialists but also by international agencies (WCED 1987, p.12; IUCN/UNEP/WWF 1991). Indigenous knowledge, with its long-term view and the contextual understanding of the local environment, can also be of value in developing a new science of sustainability. But there has been little discussion that directly addresses this area; exceptions include Oldfield and Alcorn (1991) who discussed the role of TEK mainly in biodiversity conservation in tropical forests, and Warren (1992) who emphasized indigenous knowledge mainly in crop genetic resources conservation.

Many traditional societies view the biophysical environment and human societies as being linked together in a web of relationships. This view, common among many traditional Amerindian (Tanner 1979; Berkes 1988), Asian (Callicott and Ames 1989) and African (Engel and Engel 1990) peoples, was probably common among pre-Christian European peoples as well (White 1967). The contemporary Western assumptions that the basic human relationship with nature is one of separation and dominance (Callicott and Ames 1989; Engel and Engel 1990), is not shared by great many traditional cultures. For example, from North America to Oceania, many traditional cultures cannot accept the idea that land can be bought and sold. Instead, they maintain that humans can only have use-rights over the land resource, which is something permanent and can only belong to a supreme power, not to mortals (Berkes 1989).

If traditional peoples had a pre-scientific conceptualization of ecosystems, we might expect to find traces of it today in the way ecosystems are locally conceived and used. One evidence of an ecosystem-like view comes from Indonesia where traditional systems combined rice and fish culture (*subak*), and wastes from this system often flowed downstream into brackish water aquaculture systems (*tambak*). The *tambaks* themselves were polyculture ponds, often combining fish, vegetables and tree crops (Costa-Pierce 1988). The *subak* itself was often part of a water temple system, and the entire regional rice terrace irrigation system was often managed as a system, as in Bali. Thus, the integration of *subak-tambak* systems for combined production of rice, fish and downstream crops is an ecologically sophisticated application.

Ancient conceptualizations of ecosystems, especially as watershed-based units, exist in several Amerindian, European and Asian cultures (Gadgil and Berkes 1991). But it appears that it is southeast Asia and Oceania which had, and to some extent still have, a wealth of such pre-scientific ecosystem concepts and applications. Examples include ancient Hawaiian *ahupua'a* (Costa-Pierce 1987), the Yap *tabinau*, the Fijian *vanua*, and the Solomon Islands *puava* (Ruddle et al. 1992). The *puava*, which refers to an intimate association of a group with land, reef, lagoon and all that grows on or in them. It is an integrated corporate estate (Ruddle et al. 1992), but effectively the "personal ecosystem" of the group in question: "*puava* is a defined, named area of land and in most cases sea. A *puava* in the widest sense includes all areas and resources associated with a *butubutu* (descent group) through ancestral rights, from the top of the mainland mountains to the open sea outside the barrier reef" (Hviding 1990). Similarly, in the Hawaiian *ahupua'a*, river drainage basins were managed as integrated systems, fishponds and agriculture were combined, and headwater forests were protected by taboo (Costa-Pierce 1987).

For analytical purposes, traditional knowledge may be considered at several levels. First, there is the local TEK of animals, plants, soils and landscape; all such knowledge has obvious survival value but may not be sufficient by itself for the sustainable use of resources. Second, there is the traditional resource management system, as in the Bora agroforestry example, which uses local environmental knowledge *and* also includes an appropriate set of tools, techniques and practices. Third, such traditional systems of management require appropriate social institutions, examples would include the Indonesian *subak* and the Solomon Islands *puava*. For a group of interdependent hunters, fishers or agriculturalists to function effectively, there has to be a social organization for coordination, cooperation, rule-making (as in social restraits) and rule enforcement. Finally, the world view which shapes the environmental perception and gives meaning to social relations, may be considered a fourth level of traditional knowledge. Not all TEK may be adaptive, and a given practice such as a particular taboo for the killing or consumption of an animal may be of obscure adaptive value. But different levels of TEK may be adaptive at different scales, analogous to the proximate and ultimate levels of significance in evolutionary ecology.

These different levels of TEK need to be considered together. Our impression is that there has probably been a disproportionate amount of interest in local environmental knowledge held in TEK systems (Consider the photos of befeathered New Guineans peering at obscure medicinal plants on the cover of popular weekly magazines). But there has not been a great deal of interest in traditional management systems, institutions or world views. Or worse, there is "emphasis on the *extraction* of knowledge with little, if any, indification of the place of this knowledge in indigenous societies, as in the special status which it confers to some individuals" (G.Baines, chair, IUCN Working Group on TEK, pers. comm.). And yet, the protection of local environmental knowledge held by TEK systems depends in the long run on the conservation of the integrity of TEK systems at all levels, including social and institutional.

What insights do TEK systems offer for management of resources and ecosystems? Consider for a moment that the northeast Indian *jhum* system described by Ramakrishnan (1992) employed a monoculture crop on the hill slopes year after year regardless of the ecological feedback. Such an approach may produce a reasonably good crop one year, perhaps even several years in a row. But it is not likely to produce food that would sustain a group of people in the long run. It is much more likely that a different strategy would work better for long-term survival: plant a diversity of species and varieties, make a note of which species grow best where, apply this information to adjacent areas and pass the knowledge on to your offspring. As Ramakrishnan

(1992) has shown, the multispecies strategy using a mix of C-3 and C-4 species does in fact make a great deal of ecological sense, as well as minimizing the risk of total crop failure by making sure that at least some of the crops will grow well in any given year.

Contrast this with the results of the more intensive applications of science and technology, such as the current practices of agriculture or intensive aquaculture. Resource management based on Western scientific knowledge often generates simplified ecosystems, either directly through excessive resource extraction and monoculture-based production, or through pollution and degradation that cause ecosystem stress. Subsidies to these production systems, such as energy inputs or technological innovations or the use of a series of substitutions (often with the sequential depletion of resources from elsewhere) tend to mask the degradation of the resource base (Berkes and Folke 1994).

As well, resource management practices are designed to lock out the feedbacks from the environment; resource management agencies work hard to avoid natural perturbations, as in fire management in forestry. Blocking out perturbations and feedbacks may be "efficient" in a limited sense in the short-term, but may make the ecosystem "brittle" by inviting even larger and less predictable feedbacks from the environment. These feedbacks, termed surprises by Holling (1986), may be even harder to cope with and can have devastating effects on the ecosystem and on societies that depend on these resources (Gunderson et al. 1995).

Traditional systems of knowledge are not just curiosities; they are important for rediscovering new principles for the more sustainable uses of the natural environment. Traditional knowledge and management systems, developed by trial and error through millenia, enable many societies to use their resources in a way that maintains the integrity of their local ecosystems.

The process that gives rise to TEK is the natural process of adaptation. Thus, the evolution of TEK can be seen as part of the general self-organizing process of all natural systems. Related to increasing the potential for survival, TEK evolves from the necessity for the society to deal with feedbacks from the environment. It is a capital of knowledge that contains not only the simpler, "Is this good to eat?" type of information, but also the codified information essential for societal survival on how to respond to changes in the environment, such as game depletion, soil exhaustion and forest succession. In short, it contains the recipes for responding to and managing ecological feedbacks.

5 SEARCHING FOR MECHANISMS THAT LINK SOCIAL AND ECOLOGICAL SYSTEMS FOR RESILIENCE AND SUSTAINABILITY

The general objective of our subproject of the Beijer Institute's research programme on *Property Rights and the Performance of Natural Resource Systems* is to study social mechanisms that have evolved for dealing with ecological feedbacks to secure sustainability of the combined social-ecological system. We investigate how the resilience (capacity to buffer disturbances, to absorb them) of certain selected ecosystems can be improved by learning from traditional and newly-emergent social-ecological systems. Social and ecological linkages in the management of selected resources and ecosystem are investigated systematically, using a common analytical framework, which is summarized in the following

5.1 THE ANALYTICAL FRAMEWORK

The research questions posed by the subproject explicitly link ecology, economics and social science. They require an interdisciplinary, international, case study approach. To ensure focus, creative synthesis and direction, the subproject uses a common framework for the case studies. This includes the identification of the relevant characteristics of the ecosystem in question, and the identification of property rights arrangements, institutions and knowledge systems that characterize the case study.

The framework shown in Figure 3 distinguishes seven sets of variables which can be used to describe social and ecological system linkages in any resource case study: (1) ecosystem, (2) resource users and technology, (3) local knowledge, (4) property rights, (5) institutions, (6) pattern of interactions, and (7) outcomes. The framework borrows from the Oakerson (1992) framework for the analysis of common property resources and from the framework for institutional analysis used by Ostrom and colleagues (Ostrom 1990). The following sections describe each of the attributes, followed by sections dealing with interactions and outcomes.

The Ecosystem. Particular attention is directed to factors affecting the resilience of particular ecosystems. The concept of resilience has been defined in two very different ways in the ecological literature (Holling et al. 1995). The first definition concentrates on stability at a presumed steady-state, and stresses resistence to a disturbance and speed of return to the equlibrium point. This is the conventional, equilibrium-centred, linear, cause-and-effect view of a predictive science as generally used in ecology, economics and some other sciences. In resource management science, this view leads to the assumption that resources are in fact manageable and yields predictable. Discrete yield levels, such as maximum sustained yields of fish or timber, can be calculated and perturbations (such as fire and pest outbreaks) excluded from the system.

The experience is that, the very success of such management, efficient in the short-term, freezes the ecosystem at a certain stage by actively blocking out environmental perturbations and feedbacks. Instead of allowing smaller perturbations to act on the system, management causes the accumulation of larger perturbations, inviting larger and less predictable feedbacks at a level and scale which may threaten the functional performance of the ecosystem, and thereby the social and economic activities dependent on this performance. Holling and Bocking's (1990) favorite examples are budworm control in Canadian forests (more and more control seems to lead to larger and larger infestations when they do finally occur) and forest fire suppression (following a century of fire suppression, nearly half of Yellowstone National Park burned down in one major fire in 1988).

In contrast to the first definition of resilience, the second definition, and the one we use here, emphasizes conditions in which disturbances (or perturbations) can flip a system from one equilibrium to another. In this case, the important measure of resilience is the magnitude or scale of disturbance that can be absorbed before the system changes in structure by changing the variables and processes that control behavior. This is the emerging, multi-equilibrium, non-linear view of science, Holling's (1986) "science of surprise", in which causal effects and predictions are not simple matters. Rather, systems are complex and self-organizing, permeated by uncertainty and discontinuities, as in irreversible thermodynamic systems (Prigogine and Stengers 1984). Resilience in this context is a measure of robustness and buffering capacity of the ecosystem, and associated social systems, to changing conditions.

The science in which the second definition of resilience is embedded, represents a move away from the positivist emphasis on objectivity and towards a recognition that fundamental uncertainty is large, yields are unpredictable, certain processes are irreversible, and qualitative judgments do matter.

Resource Users and Technology. The description of the social system starts with the user communities and the technology employed by them. In many case study areas, investigators will limit their case to certain resources and user communities, e.g. the fisherpersons of the Baltic, the hunter-trappers of James Bay, and the herders of semi-arid East Africa. Even within the bounded case studies, there will be considerable complexity in the user communities, the resources they pursue and the technology they use, e.g. the smaller-scale inshore and the larger-scale offshore fisheries of the Baltic (Hammer et al. 1993). The type of technology available to potential users for exploiting a resource will be important; for example, gillnets used by the small-scale fisherpersons in the Baltic limit their areas of use, whereas the trawlers of the offshore fleet will, almost by necessity, be more mobile and exploit a larger area.

The use or choice or technology may also provide clues to distinguish user communities and perhaps also the sustainability of their practices. To illustrate, in South Kalimantan, Indonesia, there are two kinds of shifting cultivators, the local indigenous forest people and urban-based, opportunistic shifting cultivators. The latter group consists of non-local, market-oriented farmers, often outfitted with chain-saws and trucks, who follow logging roads into the hills, burn the remaining timber and plant cash-crops. After 2-3 years, when the land is no longer productive, they move up the logging road and begin over. This kind of shifting cultivation is considered destructive, in contrast to that practiced by local indigenous forest people who have the capability of maintaining their environment in a productive state (Dove 1993).

Local Knowledge. Having established who the resource users are, it is then necessary to know something about their knowledge and understanding of the local environment. A farmer, fisher, logger or hunter will have a certain amount of local environmental knowledge that will allow him/her to carry out a particular activity. In many cases, this local knowledge may be very substantial, especially if it includes culturally transmitted knowledge accumulated over generations. Many indigenous groups as well as other historically continuous communities, such as certain groups of North Atlantic fisherpersons, will possess traditional knowledge (Palsson 1991). In some cases, local knowledge may be organized and used in a form that in effect amounts to a traditional management system. Such is the case with certain shifting cultivators, Amerindian hunter-trappers, Asia-Pacific aquaculturalists and others (Alcorn 1984; Costa-Pierce 1987; Gadgil et al. 1993; Berkes et al. 1994).

Of particular interest to the project are groups which may have systems of knowledge different from Western knowledge (Banuri and Apffel Marglin 1993). We refer especially to knowledge related to the maintenance of ecosystem resilience, as in the case of traditional agricultural and aquacultural systems that use a variety of species as opposed to monocultures (Warren et al. 1994), and the case of integrated human-nature concepts of the environment (Ruddle et al. 1992). There is more than one possible way to organize environmental knowledge, and the diversity of systems of knowledge and environmental worldviews deserve re-examination. Cultural diversity may be related to biodiversity (Gadgil and Berkes 1991), and both may be important for improving the sustainability of the world's ecological systems, as well as for their own sake.

Property Rights. Western resource management science often assumes a very limited set of property rights: there is state-property and there is private property, or else a "tragedy of the commons". This limited view has been criticized by many scholars and practitioners who find that the real world also contains many working examples of common-property (or communal-property) systems in which an identifiable group of users holds the rights and responsibilities for a resource (McCay and Acheson 1987; Berkes 1989; Ostrom 1990; Bromley 1992). As well, there are many systems which show intemediate characteristics of property rights, including power and responsibility sharing arrangements (co-management) between users and government agencies (Pinkerton 1989; Hanna 1990).

Property rights arrangements in a given area may be complex because resource tenure often involves "bundles of rights", ranging from use rights to the right of sale (Schlager and Ostrom 1992). Determining actual rights is often a challenge, as in many marine resources (Palsson 1991). Even within an administrative area with common legal and fiscal interventions, the actual status of local property rights to resources may vary from village to village (Jodha 1986). As well, different resources within a given area may be held under different property right regimes. For example, in the case of forest resource management in mountainous areas in Asia, patches of privately owned cropland may alternate with state-controlled and managed forest land, common grazing land, common grass and bush land from which users may be obtaining a diversity of products (Messerschmidt 1993).

Generally speaking, local social systems of rights and responsibilities develop for any resource deemed important for a community; few resources, if any, are truly open-access. Claims of lack of local property rights and self-governance often indicate lack of research more than anyting else. Even under rapidly changing conditions, there usually are incipient property rights. An historical and evolutionary perspective has often provided new management insights (Hanna 1990; Ostrom 1990). In many cases, rules arise and evolve according to local needs (Berkes 1989).

<u>**Institutions.**</u> Local and traditional knowledge do not exist in a vacuum but are embedded in local institutions. Similarly, property rights are embedded in institutions which are the set of

rules actually used, as Ostrom (1992) defines them. Rule-making, enforcement, dispute management and decision-making in general are all matters pertaining to property rights; they are also part of the question of institutions. Ostrom (1990; 1992) has elaborated on a set of eight design principles for long-enduring institutions for the management of commons.

In addition to community-based management, institutions also include questions of jurisdictions and government management agencies. Often the user community is dependent on the enforcement and protection of local rights by higher levels of government. Even those indigenous groups with well functioning local management systems are dependent on the the central government for the legal recognition of their rights and their protection against outsiders. The literature contains many examples of the necessity of local dependence on the government for the protection of communal resource management systems (Berkes 1989; Ostrom 1990; Bromley 1992). Conversely, government intervention may often be the cause of disruption of the local institution.

Patterns of Interaction. Rules, by themselves, are no guarantee for successful outcomes. In Oakerson's (1992) analysis, patterns or strategies of interaction are the means by which rules are translated into outcomes through the choices made by individuals and groups. In the case of common property resource management, such strategies include cooperation, reciprocity, free-riding, or destructive competition leading to a "tragedy of the commons". Users are interdependent, and the behavior of individual users may be modeled as a Prisoner's Dilemma game in which cooperative outcomes become likely if the "game" is repeated, if the number of players is relatively small and the probability of repeat encounter relatively large. The availability of information and the openness of communication also improve the chances of success (Ostrom et al. 1992).

Just as participants in the social system are interdependent, elements of the ecological system are also interdependent. Consider the case of a mountain watershed ecosystem. The vegetation cover, soil and surface and ground water are all interdependent. But further, the social system and the ecological system are also mutually dependent. If the ecological system on the mountain watershed deteriorates, less and less environmental benefits flow from it, and the people depending on the natural capital of the ecosystem for their crops, fuel, fiber, fertilizer and other goods will become impoverished. Damage to the functional performance of the ecosystem will likely result in damage to the social system and management institutions based on it.

Outcomes. Patterns of interaction produce certain outcomes. The biophysical environment may or may not be used sustainably; the functional performance of the ecosystem may or may not be damaged; total benefits from the natural system may or may not be optimized; and benefits may or may not be shared equitably or fairly. The question of performance of natural resource systems begs the question of evaluative criteria. Oakerson (1992) suggested two criteria, efficiency (defined as Pareto Optimality) and equity. Other criteria include empowerment and livelihood security, as suggested for example by some development professionals (ICLARM 1993).

In seeking a criterion which is both human-centric and resource-centric, and not exclusively one or the other, Feeny et al. (1990) suggested sustainability (*sensu* WCED 1987). However, there are operational problems with this concept. Whereas the criteria for ecological sustainablity are relatively well known, there are no agreed-upon criteria for economic and social/cultural sustainability. In this study, our working assumption is that social/ecological systems which have survived for extended periods of time are sustainable. This assumption is consistent with Ostrom (1990), and will facilitate the search for *mechanisms* for the resilience of the integrated social/ecological system.

5.2 HYPOTHESES FOR THE FRAMEWORK

We attempt to develop case studies that deal with both ecological and social systems and their interactions. Identifying and understanding a few of the key feedbacks would be of great value. Linkages of social and ecological systems need to deal with the relevant attributes of the ecosystem, resource users and their technology, their local knowledge, property rights and institutions, as indicated in Figure 3. But perhaps more important, the ecological-social system, the linkages and the outcomes need to be analysed from a systems point of view. The three boxes in Figure 3 may be considered components of a system, and are in dynamic interrelationship with one another. Feedback loops among the three components are indicated with arrows.

The ecological and social system, treated together with emphasis on resilience, results in certain linkages. These linkages result in certain outcomes. Depending on the outcome, the linkages may be modified. For example, the herders in a hypothetical grazing commons may see that the range is deteriorating, decide on collective action to limit the number of cattle, and decide on enforcement and sanctions, thus replacing the impending "tragedy of the commons" with a cooperative strategy. The scenario is highly plausible on both theoretical and practical grounds (Feeny et al. 1990; Hanna 1990).

The other possibility, as sketched in Figure 3, is that depending on the outcome, the interaction of ecological and social systems may be modified. One mechanism by which such a modification may come about is co-evolution. In a detailed study of Indonesian irrigation and farming systems, Geertz (1963) showed that society and the natural environment mutually modified one another over a period of hundreds of years, and that property rights institutions were closely attuned to the resources used. Another way in which the interaction of social and ecological systems may be modified is through adaptations for resilience.

Some non-Western resource management systems are of special interest because they seem to allow less intensive use and greater biological diversity, thus help maintain resilience. These are systems in which ecosystem processes (as well as populations of target species) may be maintained and ecological feedbacks managed for sustainability. *We hypothesize that maintaining resilience may be important for both resources and social institutions -- that the well-being of social and ecological systems is thus closely linked.*

It is possible that traditional and neo-traditional knowledge and resource management systems may in some ways be an improvement over conventional scientific resource management with its assumptions of controllable nature, predictable yields, and exclusion of environmental perturbations. If so, *we hypothesize that such successful traditional knowledge systems will allow perturbations to enter on a scale which does not threaten the structure and functional performance of the ecosystem and the services it provides.* Resource management under such a traditional knowledge system continuously adapts to, is modified and even evolves with these fluctuations. *We hypothesize that there will be evidence of co-evolution, making the local community and their institutions "in tune" with the natural processes of the particular ecosystem.*

Many Western resource management systems focus on high yield resources that provide a high monetary value. The production of these resources is extensively supported by the socioeconomic infrastructure, which masks the impairment of the functional performance of the ecosystem, as in modern intensive agriculture. Ecosystem simplification leads to reduced flexibility and capacity to absorb stress. In contrast many traditional knowledge systems consciously or unconsciously consider the insurance value of diversity and the information value of ecological feedbacks.

A major objective for our subproject is to analyze, through various case studies, how damages to the functional performance of an ecosystem have been avoided. That is, we aim to study local social systems that have adapated to and developed a knowledge system for coping with their resource base in a sustainable fashion. In particular, we are interested in what the feedbacks - the mechanisms serving sustainability - within and between the social and ecological systems look like, and how they are managed.

6. CONCLUSIONS AND POLICY IMPLICATIONS

The conventional resource management science, best geared for exploitive development ("business in liquidation") but not for sustainable use, is in need of fundamental rethinking. The range of changes include those regarding world views and, more pertinent to the present subject, property rights and institutional arrangements. The issue has been raised that changes in property rights through western-oriented management, from communal ownership to private or state ownership have disrupted behavioral patterns, and social-self-regulatory mechanisms that once ensured sustainable uses of environmental resources and ecosystems (Berkes 1989; Gadgil and Berkes 1991; Gadgil and Guha 1992).

We have argued that resource management characterized by traditional ecological knowledge systems allows unpredictable perturbations to enter the system, instead of locking them out. In indigenous cultures, a knowledge base has evolved to provide guidance on how to adapt to such perturbations, and how to respond to change. Such cultural practices are not only adapted to, but actively modify their natural environment by managing the feedbacks for the sustainable use of the resource base. These adaptations to the resource base have ensured that traditional societies have prevailed for extensive periods of time within dynamic ecological thresholds; those which did not, disappeared long ago. Through a number of case studies we are presently searching for the mechanisms guiding such a behavior. Each case study is designed to contribute to the overall project which will try to synthesize the following: Are there similarities, general patterns and principles, and policy recommendations that can be drawn from the case studies? What lessons can be learned to assist in the designing of more sustainable resource management systems? How can adaptiveness and resilience be built into institutions so that they are capable of responding to the processes that contribute to the resilience of ecosystems? The task is to make institutional arrangements more diverse, not less; natural system-social system interactions more responsive to feedbacks; management systems more flexible and accommodating of environmental perturbations.

As local communities and traditional peoples are integrated into the global economy, they lose their attachment to their own restricted resource catchments. This could lead to a loss of motivation to observe social restraints towards the sustainable use of a diversity of local resources, along with the pertinent traditional knowledge that goes with it. Self-interest in sustainable uses of environmental resources and ecosystems may be maintained, however, as long as the local population continues to have at least some expectation of benefits, economic or otherwise.

Common property theory provides some general guidelines and policy prescriptions for community-based management of environmental resources and ecosystems: (i) eliminate open-access conditions in areas to be conserved, (ii) balance resource-use rights of the local population with responsibilities, and (iii) legally protect land tenure and marine tenure of local communities (Berkes 1989). Sharing responsibility and benefits requires cooperative management (co-management) arrangements between the local organization and the government, and the rights and benefits may be spelled out in a management plan (Pomeroy 1993).

In this chapter, we have focused on sustainable resource management systems, and on ecological insights from local communities and traditional knowledge for the design of more diverse and more resilient systems of production. Understanding the mechanisms guiding sustainability of the combined social-ecological systems could provide insights for redirecting the behavior of the industrial world towards a more sustainable path. The irony is that, just as globalization has liberated local communities and traditional people from their local ecosystems on which they used to depend, they are receiving attention as a source of inspiration so that the industrial world does not destroy the larger global ecosystem on which all people depend.

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Figure legends

Figure 1. A systems view of the differences between common-property and open-access

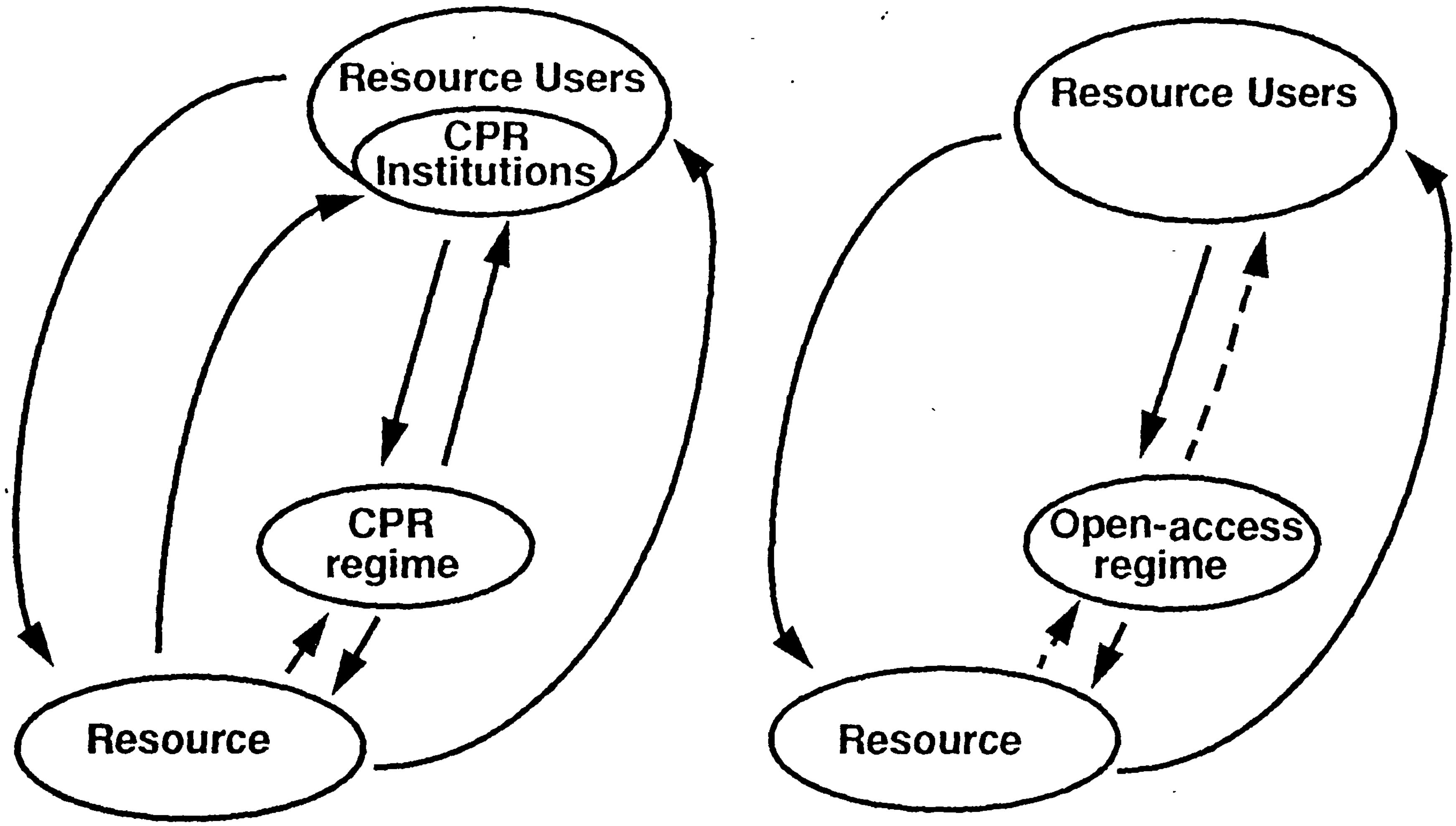
Source: Berkes, F. 1993. The Interface Between Natural and Social Systems. Beijer Discussion Paper No. 37.

Figure 2. First-order interrelationships among natural capital (NC), human-made capital (H-MC) and cultural capital (CC). Natural capital is a prerequisite, a necessary but insufficient condition for culture and welfare. Tools and techniques are created by an interplay between nature and culture. Technical development impact nature's life support systems, for good and for bad, but also the cultural view of humanity's relation with nature in a sustainable or unsustainable direction.

Source: Berkes, F. and C. Folke (1994), Investing in cultural capital for a sustainable use of natural capital. In: Jansson, A.-M., Hammer, M., Folke, C., Costanza, R. and M. (eds.), Investing in Natural Capital: The Ecological Economics Approach to Sustainability. Island Press, Washington.

Figure 3. A framework for analyzing the links between social and ecological systems for resilience and sustainability.

Source: Berkes and Folke. 1994. Linking social and ecological systems for resilience and sustainability. Beijer Discussion Papers No. 52.



A. Feedback in potentially sustainable CPR systems

B. Feedback in unstainable open-access systems.

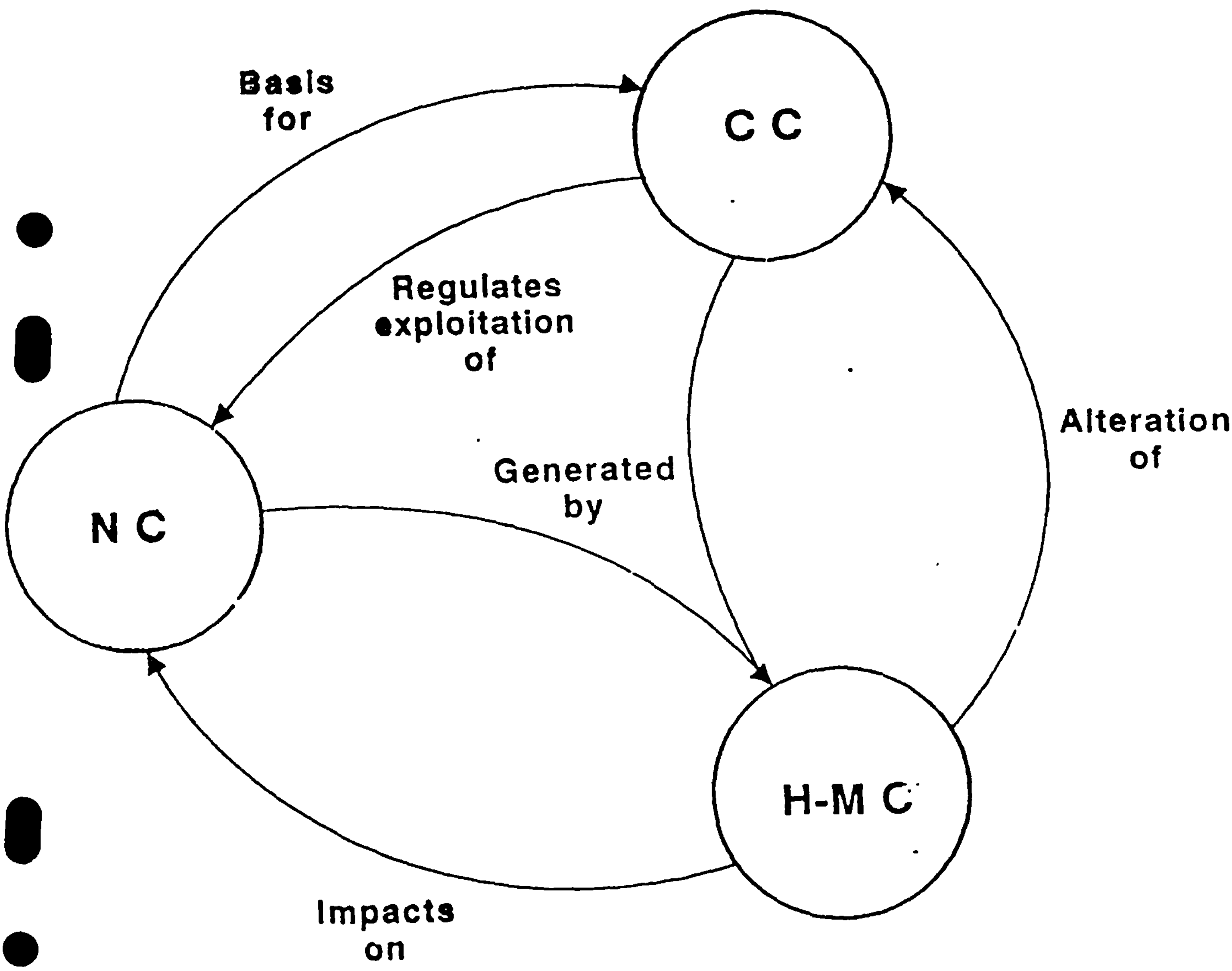

Basis for
C C
Regulates exploitation of
Alteration of
Generated by
N C
H-M C
Impacts on

Figure 1. A framework for analyzing the link between social and ecological systems for resilience and sustainability