Integrated Water Resource Management: A Human Ecological Perspective

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Abstract

Integrated water resource management (IWRM) for comprehensive and sustainable management of river and lake basins is a recent phenomenon, although the idea has been present in academia for at least half a century. The notion of IWRM and its successful implementation is worth studying for its potential benefits in both the scientific and political arenas. The main problems are: existing views tend to become reductionist in the name of comprehensiveness; most of the fields of knowledge become pockets of expertise, with limited relationships between each other, while some are taken as external boundary conditions and fail to address the problem wholly. This paper attempts, through the review of relevant literatures, to assess the reciprocity of human nature systems. The first part of this paper shows the general evolutionary trend of the IWRM and the externalities in the natural and human systems arising from this. The second part tries to connect the practice of IWRM to theoretical frameworks of human ecology according to the different scales of inquiry. Here, basin governance through different natural resource management practices is regarded as a set of "complex adaptive strategies" for achieving fairly equitable and long–term resource use.

Keywords: basin governance, ecosystem homeostasis, integrated water resource management history, natural resource management, social-ecological systems.

Introduction

The notion of integrated water resource management (IWRM) is widely debated among politicians, planners, and naturalists. However, failure in managing the resource that is sometimes referred to as "blue gold", as a resource for the global and local common good, reflects the problem of conceptualizing the dynamism of IWRM. The notion of IWRM has been developed over time, and is recognized in academia as having quite a long history. During the time in which the development of the idea has taken place, there have been significant changes in thinking and ongoing debates. Some have stressed the importance of formal mechanisms in implementing IWRM, while others have emphasized the vital function of informal sectors in the realization of IWRM. Others still have argued for a mixed approach, taking account of both formal as well as informal sectors according to the region to which the concept is applied. However, it is only very recently that the "IWRM package" has been recognized as non-linear, dynamic, diverse, and complex (Saravanan 2006).

The present paper is directed towards understanding the evolution of the concept of IWRM, as well as the ideas found in the feedback and adaptiveness that emerged from this work, before assessing the present position of the IWRM rhetoric, as expressed through its evolution. It is argued that a major reason for the failure of this idea in the implementation stage is the stress placed on *maximum* ecosystem services, which is dominant, even in relation to the idea of maximum *sustained* ecosystem services. The concept of IWRM, as emerged in the literature, is seen through the notions of human ecology. This chronological review suggests that in each stage of the development of the notion, as well as in its implementation, externalities arise accordingly. These externalities suggest a complex, as well as a compound, relationship between the human and ecological systems, whereas the internalizing of many frameworks that were previously thought of as external conditions is regarded as characteristic of adaptiveness and resilience in the management of water resources in an integrated manner. Special attention is given to the processes of basin governance, and its effectiveness in patterning ecological processes and feedback in such a way as to minimize the energy used in the planning process.

Integrated Water Resource Management and its Historical Significance

Much of the terrestrial landscape has been shaped by water over millions of years. The unique characteristic of water, that it is able to exist in solid, liquid, and gaseous forms in the temperature range of the earth–atmosphere system, makes it a wonderful "tool" with which nature has been able to shape landscapes over space and time. Water affects these landscapes in both direct and indirect ways; directly through its hydrological action, and indirectly through water's potential to influence the metabolism of all living organisms. These organisms and their complexes, such as biomes, which depend directly on water for their survival, shape their immediate landscapes as well as the earth–atmosphere system, thereby influencing the livable steady state conditions of the earth's life supporting systems. Water, thus, is at the very heart of the Gaia hypothesis as presented by Lovelock (1979). However, with the domestication of plants and animals around 13,000 years ago somewhere in the arid Middle-East (better known as the "fertile crescent"), humans significantly increased the importance of the relationship between water and the landscape significantly. Since they now depended on plants for their survival, which in turn needed water for their survival, humans started changing the landscape by creating the necessary conditions for the "domestication" of plants. What followed was a population explosion in the perennial river basin regions, with increased specialization in resource use. These specializations in resource use gave rise to large hydraulic civilizations, in the sense that all of the resources utilized within a river basin were patterned by hydraulic structures, such as dams and other irrigation systems. Some hydraulic civilizations were successful in achieving comprehensive management of their land and water resources, as exemplified by their lifestyles and the time scale (several thousand years) over which they remained as hubs of technological advances and international relations through trade (Kenoyer 1997; Yoffee 1995). The success of these civilizations, as far as long–term resource use is concerned, suggests that they must have had a plan based on the interconnectedness of the land–water systems. Based on these facts, it is presumable that an integrated approach for land and water resource uses in this sense is older than the idea itself.

The notion of IWRM as an academic discipline came much later. Perhaps the earliest roots of IWRM can be traced back to the 1930s, with the commencement of Multi–Purpose River Valley Projects (MPRVPs), such as that of the Tennessee Valley Authority, which marked a new era of integrated resource management. Although the main aim of these projects was to use the then rapid technological advances to extract the maximum possible yield from the watersheds, nevertheless, they did try to include "water systems" with other ecosystems and a knowledge of both terrestrial and aquatic ecosystems, as erosion and pollution control, etc., were necessary (Mukhtarov 2007). However, as this approach looked at resource management for maximum possible yield, it looked at natural systems objectively, and human systems were considered to be beyond this sphere. Later, the works of White (1961), Simon (1957) and Wolpert (1964) brought the characteristics of decision-making processes for resource management into focus. White (1961) showed that culture and resource management institutions had a greater influence on decision-making than the immediate physical environment. Simon's (1957) and Wolpert's (1964) works showed that decision-making for resource management was based on imperfect knowledge, rather than perfect knowledge (Hooper 2003).

The search for a compromise that was reflected in an integrated approach to land, water, and ecosystems started around the 1960s. This integrated approach (also conceptualized as "second generation IWRM") took shape in response to widespread negative consequences from the misuse of interactive land and water systems, mainly reflected through the declining quantity and quality of available freshwater (de Jong et al. 1995), although this new concept took some time to develop a stronghold in academia, which occurred in the 1980s. The idea of water resource management as an interaction between land, resources, and the environment was well stated by Burton (1984) in his article, *The Art of Resource Management.* Burton argued for a land–use appraisal of resource use. However, even at that time, integrated management of water resources still meant *maximum* possible human uses. Biswas (2004), following a review of literature from the last 60 years, identified many elements of the related frameworks that constitute the IWRM rhetoric. A summary list of these elements is given below:

- Economic efficiency, regional income redistribution, environmental quality, etc.
- Water supply and demand
- Surface and groundwater
- Water quantity and quality
- Rivers, aquifers, estuaries, and coastal waters
- Wastewater
- Water projects
- Urban and rural water issues
- Water institutions
- Public and private sectors
- Government and NGOs
- Legal and regulatory frameworks related to water
- Economic instruments for water management
- National, regional, and international issues
- Intrastate, interstate, and international rivers
- Bottom–up vs top–down approaches
- Centralization and decentralization
- National, state, and municipal water policies
- National and international water policies
- All social groups
- Gender–related issues
- Climatic, physical, biological, human, and environmental impacts

- Present and future generations
- Present and future technologies
- Water development and regional development (Biswas 2004).

However, the implementation of this broad, all–encompassing concept has been far from successful. Biswas suggests that the main reason for this failure is the increasingly reductionist approach to the different "epistemic frameworks" provided by the indicators of the integrated water resource management. These include different disciplines, together with their theories and institutions, including water, environment, economy, society, communication, technology, geography, and many more. Together, they form such a vast field of knowledge that mastering all of them is quite impossible (Biswas 2004). Therefore, the potential allocation of equal importance to each of these criteria is an impossible task, rendering the concept of *integration* a utopian ideal.

One of the most significant contributions to the IWRM rhetoric, as far as the problem of reductionism of ideas is concerned, has been the work of Mitchell (1991). As Hooper (2003) found, Mitchell's approach was focused primarily on ecosystem–based natural resource management principles. However, his emphasis was on the use of *specific* components, based mainly on stakeholder knowledge, for an integrated approach to resource management. The concept of IWRM had been under development for a long time, gaining momentum with the new environmental movements of the post 1970s, which promoted wide-scale reductionist ideas in the name of comprehensiveness. Mitchell's work tried to address this problem with a strategic approach based on stakeholder knowledge as a means of achieving holism. Mitchell's approach enables effectiveness at the implementation stage, unlike the comprehensive approach. One of the greatest drawbacks of his idea, however, was that although it was based on an ecosystem approach, human systems were not included, being regarded instead as external boundary conditions.

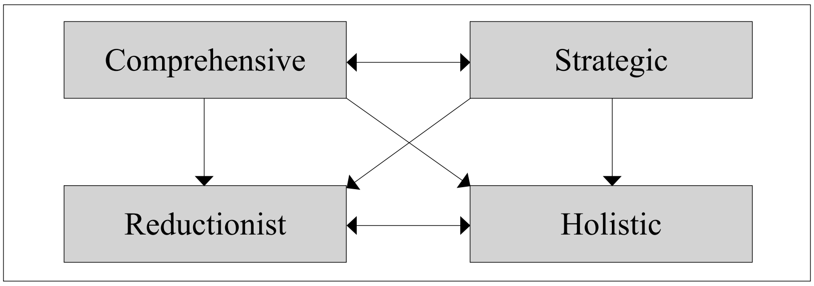
The different stages in the development of the IWRM concept are shown below, and indicate a trend in thinking from maximum possible ecosystem services to maximum sustained ecosystem services, given the same exemplary externalities.

Table 1: A literature review of the IWRM rhetoric

WRM in the past	Planning Procedure	Emerged externalities	Literature
Prior to 1930s	Single purpose	Organization of ecological processes in the human system extremely dispersed. Objective view of nature. Lack of linkages between human system and the ecological processes. Culture.	White 1998
1930s – 1960s	Multi Purpose (First-Generation IWRM)	Organization of ecological processes in the human systems is still dispersed. Objective view of nature. Lack of linkages between human system and the ecological processes. Culture.	Water Projects for maximum possible yield (TVA, Aswan, DVC)

1960s – 1990s	Land-, water-, and ecosystem-based management (Second-generation IWRM)	Lack of linkages between human system and the ecological processes. Culture.	Simon 1957 White 1961 Wolpert 1964 Burton 1984
Post 1990s	SES	Information–flow pathologies, unsustainable utilization of human behavior.	Lee 1992 McGovern et al. 1988 Gleick 2000 Mitchell 1991 GWP 2004

Figure 1: The four problem modules with IWRM



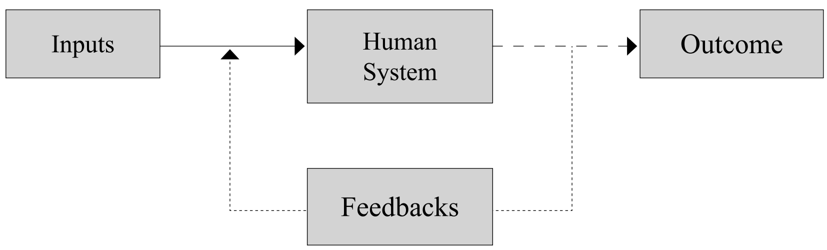
Based on Table 1, we can find four problem modules for the conceptualization of IWRM (see Figure 1). These four problem modules are also associated with all other natural resource management practices, and reveal two major dichotomies, the first arising between comprehensive and strategic approaches, while the second is between reductionist and holistic approaches. The existing literature suggests that a comprehensive and holistic approach requires such a lengthy time frame that it is a near impossible task. Comprehensive approaches have thus tended to become reductionist, because it is much easier to draw knowledge from the pockets of expertise that exist within the different elements of natural resource management, for example, the elements concerned with water management listed earlier. The strategic–reductionist approach has perhaps been the most widely implemented for the management of water resources. This constitutes a direct utilitarian concept, reflected in structural management methods such as dam building and irrigation expansions, and by single–sector approaches, such as river basin management practices prior to the 1930s. Gleick (2000) suggests that IWRM indicates a transition from a directly utilitarian concept of better utilization of resources that were thought to be of unlimited quantity to an indirect utilitarian concept involving better utilization of *finite* resources. External boundary conditions (meaning conditions that do not have a direct influence on the system) arise in each of these cases, giving rise to negative environmental externalities, with the outcome being both quantitative and qualitative deterioration of resources at the receptor level. This is most prominent in the case of the strategic–reductionist approach. Before White's work, culture was a major external boundary condition, for example, in either the strategic or the integrated approach to the management of natural resources. However, the attribute of culture is being reconsidered in any natural resource management rhetoric, especially that associated with adaptive management, which is at the heart of human–environment or social–ecological systems discourse. Likewise, in water resource management prior to the 1930s, where the trend was toward single–purpose approaches, certain purposive management practices, such as dam building, viewed irrigation as the sole internal boundary condition. Processes such as recreational use or biodiversity conservation in the riparian states were external to the management system in this sense. With the emergence of MPRVPs following the 1930s, internalization of many attributes became possible, but in general they continued to concentrate on strategic interests, while the vital parameter of *interactions* between different strategic interests were not taken into consideration. Thus, in this phase, interactions were not included as external boundary conditions in the water resource management system. The internalization of interactions between land, water, and ecosystems came with the second generation of IWRM, especially following the 1990s, when water resource management began to be seen as integrated land and water resource management (ILWRM).

An essentially human ecological approach to the management of river basins has been adopted in recent years, especially since the 1990s. This trend has followed the main criteria of basin management, with human systems seen as integral in natural resource management. This has seen the establishment of the notion of the social–ecological system (SES), the concept of which, as it relates to IWRM, is described in the following section.

Social–Ecological Systems and the Causes of their Collapse

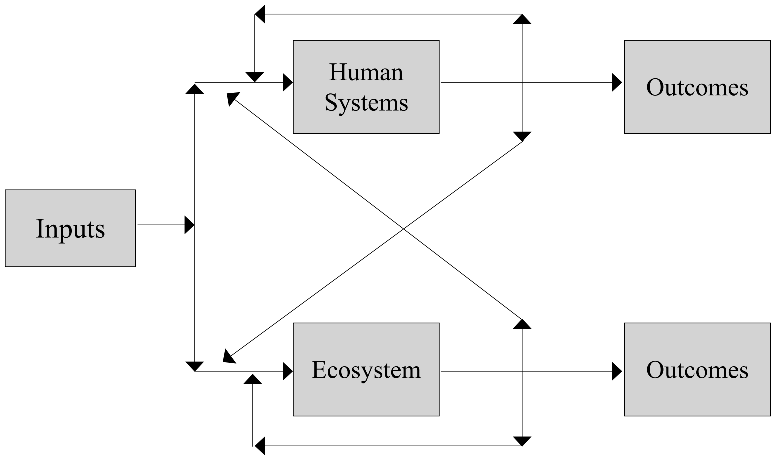
The interactions between resource pools and human systems are not separate phenomena. Thus, the criteria of integration in its broadest sense are related to the interactions between the human, or social, and the natural, or ecological, systems (see Figure 3). Together, they form social–ecological systems (SES) (Anderies et al. 2003). The importance of these two components, which are at the heart of the dimensions of IWRM, has also been described by Jonch-Clausen & Fugl (2001). In contrast to the objective view of nature, which focused on optimum resource use and thus profit maximization, the notion of SES allows resource managers to take a subjective view of nature, whereby the social systems are seen to be embedded within it. Thus, it is, in essence, an indirect utilitarian concept. This relationship is represented by a simple feedback system as shown in Figure 2 below. However, this simple relationship is not likely to be realized in reality, where the prevailing condition is more likely to be a complex–compound relationship (see Figure 3).

Figure 2: The relationship between the human system and the environment



Complex–compound relationships involve an array of different sources, pathways, and receptors for social–environmental outcomes. This explains the non linearity, diversity, and dynamism of the IWRM rhetoric, and this kind of relationship gives the whole system more resilience because the collapse of certain components does not necessarily lead to the collapse of the whole system (Anderies et al. 2003), an attribute that makes social–ecological systems adaptive to change. For IWRM, the natural system is given by the resources available in the land–water systems, the mutual interaction and evolution of which tend to maintain SES. A decomposition of human systems, on the other hand, provides the analytical frameworks of all the different stakeholders and their activities, as expressed through their use of the land. These different land uses can be taken as characteristics of the human system concerning the collapse or sustainability of natural resources.

Figure 3: Complex–compound relationship in a social–ecological system

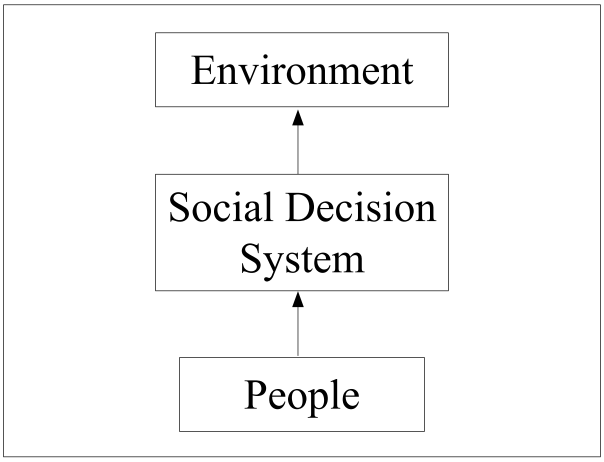


The most glaring example of mismanagement leading to the collapse of resource systems for use of the commons was discussed by Garrett Hardin (1968) in his work "The Tragedy of the Commons". Hardin pointed to the freedom of the commons, or people, regarding their decisions for resource use. He showed that an increment of a positive component of, say, a domesticated animal such as a cow, leads to an increment of a negative component, overgrazing, created by that additional animal. These two components will force pastoralists to maximize their "goods", which in this case are the services from the animals. Furthermore, as resource systems are finite relative to the growth of the population, the cumulative increment of the negative component described above may lead to a possible violent consequence as far as resource depletion is concerned.

The idea of common pool–resources (CPRs), the mainstay of Hardin's argument, is now well embedded in resource economics. CPRs represent those types of resources that do not have clearly defined property rights. Grazing lands, irrigation systems, lakes, river systems, and fisheries constitute the most common examples of such resources. Together, the economic activities of man, or the "commons", and common–pool resources are often caught in a vicious cycle of overexploitation, thereby leading to resource depletion. Furthermore, as the well–being of the commons is directly related to the state of the CPRs, human lives are also adversely affected. Hardin's argument also applies to the exploitation of open–access resources. Here, conditions are more conducive to resource collapse, as there is *no restriction* on resource use. The criteria of common-pool resources are well explained in the work of Becker and Ostrom (1995). They argue that the characteristics of common-pool resources are represented by two master factors, exclusion and subtractibility. These two factors determine the "tragedy of the commons" phenomenon relating to the governance of common-pool resources. Exclusion means deterring others from using the resource; in simple terms, it is about placing restrictions on use. It is controlled by the conditions of property rights, and may be broken by the "free riding" behavior of individuals or groups towards others aimed at ensuring the long–term utilization of a resource. Most natural resource management planners call for an imposition of exclusion through private property schemes, their main aim being to internalize the free riding described above. However, more often than not, these schemes have failed to achieve their objective, in the worst cases causing further deterioration in the health of the ecosystem, or creating a greater resource inequality within the community (Runge 1981). Subtractibility, on the other hand, is the condition of diminution of a resource due to usage. As a result, resource availability is unevenly distributed over space and time. The characteristics of common–pool resources also include mobility or storage, and whether they are physical or biological (Becker & Ostrom 1995). In the case of water, mobile water and stored water offer completely different options in terms of both management and use. Furthermore, the existence of water in the earth's biosphere is associated with life forms, certain parts of which may be regarded as a resource for society. Therefore, water in a dam is a physical resource; water in a fishery is not. Water is, therefore, neither a purely physical nor a purely biological resource, but has the characteristics of both. These attributes make the governance of water as a common-pool resource challenging, as far as its long–term usability is concerned, relative to management of other natural resources.

Apart from Hardin's classical idea, and the second generation of ideas that evolved from Hardin's framework, like those put forward by Becker and Ostrom, other scholars, like McGovern et al. (1988) concentrated on information–flow pathologies as some of the main forces behind sustainable social organizations, which tend to affect the sustainability of SESs. According to McGovern et al., lack of or flawed information flow may occur for several reasons, such as over–generalizations of information available within one type of ecosystem, applying one ecosystem model to several ecosystems, managerial detachment from the resource–user communities such as agriculturalists, inadequate observation, ideological beliefs (Lee 1992), and moral and ethical considerations by the managers. These problems then give rise to formal solutions, which result in less than favorable outcomes and make the social–ecological systems less resilient to necessary changes for long–term resource use. The degree of divisibility of the different resource categories is another attribute that affects the management of natural resources. The notion of unsustainable utilization of human behavior is actually quite old. Zimmerman (1951) and Firey (1960) were the main proponents of this idea. They proposed that the perceived values of certain ecological processes affect the behavior of individuals and communities. These values, according to Firey, must be internalized, and must be recognized by the society as gainful to both the individual and society (Firey 1960). Conservation of ecological processes by local farmers is an example of internalization of ecological values. Furthermore, the internalization of ecological values is related to culture and traditional knowledge, as expressed by White (1998) and discussed above. The interaction between the common–pool resources and the commons is, therefore, associated through the array of social decisions that constitute the meta–system of human–environment interactions, which have been inadequately addressed by both the market and state institutions (Carpenter 1998). A simplified explanation of this relationship can be seen in Figure 4 below.

Figure 4: Environment as affected by people's economic activities



The next section addresses the process of institutionalization of the ecological processes through understanding the feedback patterns and building resilience in human institutions, both of which are actually an attempt at "co-adaptation" with the changing circumstances of a social–ecological system. Here, I propose a reorganization of the IWRM thinking from the macro scale, based on the theory of evolution, to the meso scale, based on the different natural resource management approaches, to the micro scale, based on the interaction of human institutions with the natural environment as a means of achieving long–term resource use.

Basin Governance as a "Complex Adaptive Strategy" for Ecosystem Homeostasis

Co-adaptation, co-evolution, and ecosystem homeostasis: understanding evolution
Natural resource management practices tend to arise from efforts aimed at controlling certain environmental characteristics of a given region for human consumption. This utilitarian nature of management practices has been at the heart of ecocentric management, such as conservation of biological diversity. The main question raised by such practices is, "If we cannot protect other species from human–induced extinction, can we protect ourselves from the same?" In the case of IWRM, this conservationist thinking can be related to the concept of maintaining environmental flows with a view to maintaining ecosystem health. I call this the indirect utilitarian concept. This should be quite easily distinguished from the direct utilitarian concept, which is an objective view of nature as expressed through technocentric thoughts. Any natural resource management practice, such as damming a river or building cities and transportation networks, falls into this category.

The framework of basin governance of any natural resource management program can be divided into three stages, according to the scale of inquiry. The broadest is the macro scale, which originates from the Darwinian theory of evolution, and thus is at the heart of human ecology. The notion of IWRM through basin governance falls very much within the domain of social–ecological systems, which constitutes the efforts of human beings to make themselves and their activities "fit" with the surrounding environment for the long–term use of a particular natural resource. Thus, if the environment changes, then human activities, and therefore resource management practices, must also change, to make them fit with the surrounding environment. This "changing together" and "fitting together" has been recognized as co-adaptation and co-evolution (Martin 2001). Natural resource management requires planning at different levels of decision-making. As human society composes a system that interacts with the environment through either collective or individual decision-making, these decisions determine the level of organization of the social systems within the environment. Dakin (1963) stated that planning is "a careful balance between efforts to draw energies together." The "energy" in Dakin's explanation is nothing other than the complexity that arises as a result of collective human actions within the environment. These collective human actions need to be held together in some *way* to "reduce the entropy and increase organization within an environment" (Burke and Heaney 1975). The importance of such organized behavior is to make human actions fit with the environment with minimum energy spared. This energy minimization can help to reorganize the system according to the feedback it gets, both from the inputs drawn from nature and outputs to nature. The reorganization leads to the changes needed to make the social system fit with the environment. Thus, the human systems make them adaptive to the environment in response to the changes in that environment. An example of this was provided by the simple feedback relationship described above.

Natural resource management for ecosystem homeostasis: patterning feedback

At the meso scale of IWRM thinking, the various natural resource management practices can be taken into consideration. Natural resource management practices are actually ways of understanding the feedback provided by ecological processes in response to naturally or anthropogenically induced interventions. Natural resource management practices can be divided into three broad paradigms; adaptive management, ecosystem–based management, and community–based management (Bocking 2004). Adaptive management refers to the efforts of human institutional systems after regional development or environmental preservation projects have been implemented. Environmental impact assessment is the most common example of adaptive management. Ecosystem–based management, on the other hand, refers to the priority given to nature, which is mainly seen as objective, for human consumption. This type of management can be further subdivided into three categories, i.e. management through single–species inquiry, through the array of different activities that are possible, and the array of different goals that may or may not be achieved as far as a common resource is concerned. Each category of ecosystem–based management has its own drawbacks. Management through single–species inquiry is easily carried out, and requires much less effort and time to understand the state of the ecosystem. However, it does not provide any information about the state of other species within the ecosystem, such as an increase or decline in population due to management practices. The *real* state of the ecosystem, thus, is never known. The state of the ecosystem as judged through the array of different activities that can be carried out concerning a common resource, as well as goal–oriented ecosystem management, takes a primarily objective view of nature, concentrating mainly on how much can be extracted from nature. The question is therefore, how much consideration in real terms is given to the state of the ecosystem?

The third management paradigm involves the community–based attempt to make human systems fit into the natural systems. This approach is concerned with resource management through local community effort, and with acknowledging the importance of local knowledge in determining resource use. To the extent of whatever spatial and/ or temporal scales they apply to, these management practices are actually an effort to fit the current production at the primary, secondary and tertiary levels to the environmental circumstances in which they are situated, and also to some extent to the possible future circumstances in which they may find themselves. Furthermore, this attempt to make human activities fit the natural circumstances asks for resource use on an optimum scale. The biggest drawback of community–based natural resource management practices is that it requires the use of community's knowledge. Traditional knowledge regarding long–term resource use is not a unidirectional phenomenon; there are many other attributes that are involved. Diamond (1997) has provided a detailed description of such attributes in his popular book *Guns, Germs, and Steel: The Fates of Human Societies*, and he argues throughout the book that the collapse or sustainability of human societies is a factor of the environment itself. The main aim of management practices, such as those outlined above, is to increase the knowledge base of resource managers, in both the formal and the informal sectors, to better cope with the dynamism and complexity of the environment.

Human institutions and resource–user communities for resource use: patterning ecological processes through resilience

At the micro level, different resource management institutions come into play when it comes to resource use. These institutions may be either formal or informal in nature. It is the combination of these institutions and their decisions that make resource use possible in a given river basin. These resource management institutions tend to combine the social decisions in a collective way for resource governance. The aim of the resource-governing institutions is to give a *pattern* to the ecological processes in order to build resilience. The dichotomy between the words "governance" and "government" is worth mentioning here. The words "governance" and "government" are often used interchangeably where management of natural resources is concerned, but they are substantially different. The latter is associated with "official" control over a tract of land or country, while "governance" is different in the sense that it is associated with the "activity" of controlling or managing a tract of land or a country. Therefore, the essence of it is related to the different actors or stakeholders at the various levels of society. The collapse or sustainability of natural resources is thus strongly related to both terms, the governance of the natural resources as performed by all the stakeholders, and/or the *official control* of the resources by a few. Social systems tend to find and use a pattern to utilize natural systems. This is referred to as the "institutionalization of ecological processes" (Lee 1992). There is a growing literature mentioning the importance of institutional reforms to institutionalize the ecological processes (Bandaragoda 2006; Ferragina et al. 2002), regarding either stakeholder involvement taking a participatory approach for resource management (Moigne et al. 1994; Newson 1997; Global Water Partnership 2000) or market–based instruments, such as water pricing (Dinar 2000). The main aim of the resource–governing institutions is to draw the necessary energies together for efficient resource use: in other words, to institutionalize the resources for better management. Furthermore, these institutions may fail to include all of the resource–user communities that have a substantial impact on the resources. Here, adverse situations arise when there are externalities between the resource management institutions and the unaccounted resource–user communities in land–use decision-making. Furthermore, these externalities may come into play with either a lack of or incomplete information (McGovern et al. 1988) about the local environment and changes in it; they may be the outcome of unsustainable utilization of human behavior (Firey 1960). As stated above, information patterns play a vital role in the feedback loop of the complex–compound relationships of social–ecological systems (see Figure 3). This may lead to unsustainable utilization of human behavior, an example of which can be seen in land use practices such as the removing of climax vegetation cover on the steep slopes for agriculture. These practices have a direct negative effect on the resilience of the whole system.

Conclusion

Based on the preceding discussion, it can be said that it is quite unlikely that river basin governance mechanisms such as SESs will come up with a unique and holistic solution that addresses all the problems related to sustainable use of land and water resources. A major drawback to the realization of the concept of IWRM has been the emphasis placed on maximum ecosystem services, rather than sustained ecosystem services. It is primarily due to this that pockets of expertise have evolved with limited relationships to each other, as identified by Biswas. Thus, the thinking has failed to integrate the social–ecological processes at work in IWRM rhetoric. Nevertheless, resource–governing institutions can improve their robustness by building resilience in the system, as outlined by scholars such as Becker and Ostrom (1995), Millington (1999), Mitchell (1991) and Burton (1984). Becker and Ostrom concentrated on a sense of defined boundaries, active monitoring, conflict–resolution mechanisms, accountability, resource tenure rights, and violator sanctions for institutional robustness, whereas Millington and Mitchell stressed the importance of strong knowledge and community awareness, a cross–sectoral approach involving all possible natural resource issues, and strong legislative frameworks compatible with the existing situations. Burton argued for land–use appraisal for water resource management in an integrated manner. Governance of natural resources, thus, is a complex process. First, this is due to our evolving awareness about the interaction between different components of natural resource systems, which tend to affect the decision–making systems regarding their long-term management. Second, as the social decision–making systems evolve, as represented in resource governing institutions, coupled with the complexity of the resources they tend to utilize for human consumption, they become capable of making themselves fit the interaction between people and nature for long–term resource use through internalizing the externalities as experienced through feedback from the ecological processes. This results in the social decision-making system emerging as adaptive strategies for sustained resource use, which is well exemplified by the ongoing trend in the paradigm shift in IWRM rhetoric, as observed in literature since the 1930s. Many notions are internalized in the planning system, as stated above. However, problems occur in the implementation stage due to information–flow pathologies, unsustainable utilization of human behavior for resource use, and the conditions of exclusion and subtractibility. Thus, resource governance can be seen as complex adaptive strategies, with the resource–governing institutions being complex adaptive systems. The efficiency of these complex adaptive systems in delivering equitable and long-term resource use should increase with their potential to internalize the possible externalities, and thereby reduce the amount of energy that is spared to a minimum.

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