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Can Integrated Water Resources Management sustain the provision of ecosystem goods and services?

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Abstract

Society derives a wide array of important benefits from biodiversity and the ecosystems in which it exists. These ecosystem services are essential to human existence and operate on such an overarching scale, and in such intricate and little-explored ways, that most could not be replaced by technology. Accordingly, approaches to integrated water resources management (IWRM) do not regard the ecosystem as a "user" of water in competition with other users, but as the base from which the resource is derived and upon which development is planned. A goal of IWRM should be to maintain, and whenever necessary, restore ecosystem health and biodiversity.

Achieving the sustainable use of water resources and thus the maintenance of ecosystem services requires a rediscovery of the hydrological cycle and the water resources system. Such a rediscovery could;

- identify characteristics that are critical to the provision of ecosystem services with emphasis on biophysical, economic, social and environmental characteristics and linkages in the system,
- provide improved understanding of the behaviour of the interactions of the system, leading to the ability to provide cause and effect predictions and ultimately,
- manage the water resources system guided by both biophysical and socio-economic indicators, end-points and value systems applicable to this rediscovery.

In this paper, the concept of an ecosystem approach to the management of water resources is assessed in the light of a reanalysis of the hydrological cycle. The approach to maintenance of ecosystem functioning in South Africa through the so-called Resource Directed Measures is considered in the light of this assessment. It is concluded that there is a danger that, traditional command and control approaches to management of the water resources system will continue to be applied under the banner of IWRM and that this will result in the failure of natural systems to sustain the provision of ecosystem goods and services.

Keywords: Ecosystem goods and services; Water resources management; South Africa

1. Introduction

Humans depend on the integrity of natural systems to provide the goods and services they need for survival. In many parts of the world, the limited availability of clean, fresh water is the major constraint to further social and economic development. In arid and semi-arid countries, a burgeoning population, pressing development needs and increasing environmental awareness are rapidly accelerating the demands for water (Kirmani and Le Moigne, 1996). It has been suggested that the rising demand for water and the degradation of its quality, represents the most serious threat to the provision of various goods and services required by society (FAO, 2000). The worldwide movement towards integrated approaches to provide solutions to major problems, including the management of natural resources, such as water, represents a significant shift towards management focussed on the sustained use of these resources. In the water resources field, this shift has found expression in the form of Integrated Water Resources Management (IWRM), most definitions of which identify that IWRM should meet human requirements for the use of freshwater, whilst maintaining hydrological and biological processes and biodiversity which are considered essential for the functioning of ecosystems,

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the sustainable use of water resources and the maintenance of goods and services provided by them. Worldwide, this is a concept that is being increasingly put into practice and incorporates much of the philosophical framework of "ecosystem management".

However, there is a significant knowledge gap between management practice and the theory and philosophy that has lead to the inclusion of these concepts as policy in South Africa and elsewhere. Consequently, there is a danger that this knowledge gap will result in a misunderstanding of the role of the hydrological cycle in the sustained provision of ecosystem goods and services. For example, approaches to the implementation of IWRM may recognise that aquatic ecosystems are amongst the important users of water, but this tends to divert attention from their role as providers of water resources and other goods and services, with the result that limited recognition is given to the critical importance of these as a basic element of IWRM. In particular, goods and services such as timber or crop production, derived from the movement of water, in the form of water vapour through terrestrial ecosystems are neglected. Thus, there is a danger that ill-considered responses to the rising demand for freshwater could sever ecological connections in the hydrological cycle and alter the quantity, quality, and timing of freshwater supplies on which terrestrial, aquatic, and estuarine ecosystems depend.

The past decade has seen many calls for better awareness of how the water cycle works, the effect of land uses on the water cycle, the importance of wetlands and other key ecosystems and ultimately how to use water and aquatic resources sustainably (IUCN/UNEP/WWF, 1991; Acreman, 1999). In South Africa, water law includes the concept of the "Reserve", which is defined as the quantity and assurance of water, as well as the quality of water, which are required to protect basic human needs and to protect aquatic ecosystems in order to secure ecologically sustainable development and utilisation. The so-called Resource Directed Measures attempt to provide for the implementation of the reserve concept, and some practical methodologies for determination of the quantity and quality of water required to maintain ecosystem functions and services have been developed (DWAF, 1999; MacKay, 2000). However, there is has been much debate in hydrological and aquatic science circles about these concepts, and the question "Do we need to rethink our approach to the reserve?" has been asked. In this paper, the knowledge gap between IWRM policy and practice is explored through analysis of the hydrological cycle, and the approach to maintenance of ecosystem functioning in South Africa through the so-called RDM is considered in the light of this analysis. However, in order to understand these issues more fully, some analysis of the concepts of ecosystem services and sustainability is necessary.

2. Ecosystem services and sustainability

2.1. Ecosystem services

Society derives a wide array of important benefits from biodiversity and the ecosystems in which it exists. Ecosystem services are essential to human existence and operate on such an overarching scale, and in such intricate and little-explored ways, that most could not be replaced by technology (Daily, 1999). These services are generated by a complex interplay of natural cycles, powered by solar energy and operating across a wide range of space and time scales, and incorporating both biotic and abiotic components.

Ecosystem functions can be considered as 'the capacity of natural processes and components of natural or semi-natural systems to provide services and goods that satisfy human needs (directly or indirectly). Generally, ecosystem functions are grouped into four categories (after De Groot, 1992): regulation functions, habitat functions, production functions and information functions. The movement of water through the biosphere provides for the production (e.g. crops, timber, cattle), information (e.g., nature experiences, aesthetic information), and regulation (e.g., formation of topsoil, sequestering of CO^2, assimilation of nutrients) functions of the environment, as well as the provision of hydraulic habitat in aquatic ecosystems.

2.2. Sustainability, sustainable use and sustainable development

Social and economic development necessitates the utilisation of, and thus impact on, natural systems. This modification of natural systems results in a trade-off between the additional (artificial) benefits gained and those which are lost as human adjustment negatively impacts on some natural functions, and this undermines the benefits of natural services provided to society. Where ecosystems are over exploited, their ability to provide these goods and services is lost. Ecosystem approaches to management acknowledge that economic growth and development must take place, but that it should be complementary, rather than antagonistic to environmental protection (Niu et al., 1993). The goal, therefore, is to optimise the mix of benefits to be gained by society from both the natural and artificially derived services provided by harvesting resources from any particular ecosystem (Fig. 1).

Furthermore, the wise re-investment of benefits derived from the utilisation of the ecosystem provides a basis for ongoing sustainability of the resource. However, if the utilisation of the goods and services provided by the ecosystem is purely exploitive, a cycle of unsustainable use may be initiated.

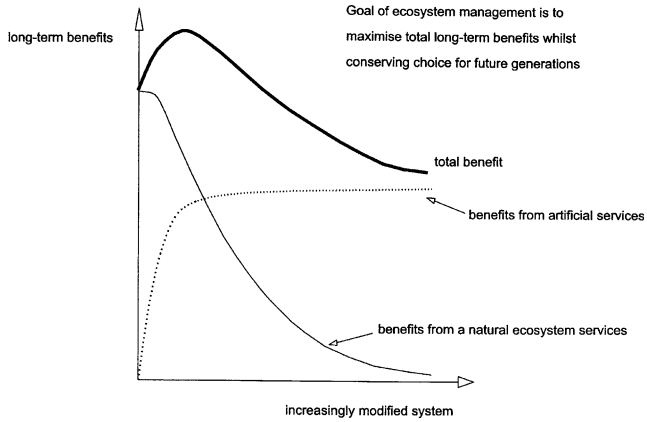

Fig. 1. Maximising the provision of goods and services (after McCartney et al., 2000).

Sustainable development has been defined as, development that meets the needs of the present without compromising the ability of future generations to meet their own needs (Brundtland, 1987). Sustainability can be viewed simply as "the ability to maintain something undiminished over some time period" (Lélé and Norgaard, 1996), or as an "ongoing endeavour ... rather than a final state that implies the persistence of a system through time" (Sneddon et al., 1996). There are many other definitions of sustainability; however, they almost always share a common theme: that development of a resource should be regulated such that the characteristics, resilience and integrity of the resource in question are protected and maintained within agreed limits.

The role of resource managers is to implement and devise policies that fulfil the goal of sustainability, thus placing responsibility on the environmental scientist to gather knowledge and produce tools to assist these managers. For many, the principle of sustainability has become a rallying point for the potential resolution of the growing conflicts between environment and economy (Yin and Pierce, 1993) and ecological sustainability has been defined as the intersection of societal values and ecological capacity. It thus reflects, on one hand, the recognition of increasing demands on a finite resource base and potentially rapid changes to the quality of natural resources and, on the other, political necessity to act in response to economic realities (Yin and Pierce, 1993). This implies that cognisance must be taken, in an integrated manner, of the complexities of the biophysical system under consideration and the social aspects they encompass.

3. An ecosystem approach

Current thinking amongst ecologists with regard to achieving sustainability, emphasises the need to conserve biodiversity at multiple scales within a landscape, along with the ecological processes within it and by doing so preserve biodiversity and ensure sustainability. Often, this is described as "ecosystem management" and is aligned with a broader process to mediate resource management so that it integrates ecological, economic and social factors in an equitable way. Despite the initial development of the ecosystem approach as a research paradigm, political level agreements have accepted that an ecosystem approach to management should allow society to harness the functioning of ecosystems and ensure the sustainable use of resources, services and goods that they provide. Ecosystems are highly variable, dynamic and selforganising systems (often termed complex adaptive systems) and any management approaches involve dealing with uncertainty. A key aspect of this approach is that the maintenance of diversity in ecosystems builds resilience against large disturbances. The resilience of a system is a measure of the magnitude or scale of disturbance that can be absorbed before the system changes irreversibly in structure, resulting in the permanent loss of the goods and services associated with it. Ecosystem integrity is the term most often used as a measure of "wholeness" and ability to continue to function in a natural way (De Leo and Levin, 1997). The integrity of freshwater ecosystems is a function of ecological connectivity operating across a range of spatio-temporal scales.

It has been noted by various researchers that ecosystems operate at many scales, both spatial and temporal. Therefore, an ecosystem approach to management may have a hierarchical context that views smaller ecosystems as nested within increasingly larger ecosystems and that defines the boundaries and scales of ecosystems which should change and evolve in response to both human and natural events (Kay, 1993; USDA, 1996; Haufler et al., 1997). Ecosystems do not have permanent or absolute boundaries and the structure and function of ecosystems change through space and time. Consequently, there is a need to address both spatial and temporal sources of variability and thus diversity, when applying an ecosystem approach to management (USDA, 1996). Multiple factors need to be considered at multiple scales with multiple boundaries.

3.1. An ecosystem approach to IWRM

IWRM has made its way to the forefront of environmental research very much in conjunction with the concerns about sustainability (Voinov and Costanza, 1998) and the recognition that existing administrative and socio-geographic boundaries are not able to account for both the socio-economic and ecological features of existing systems. It has been suggested that catchments (watersheds or river basins) provide an alternative to existing system boundaries, as they may account for both the ecological and socio-economic properties of an area (Reid and Ziemer, 1997; Voinov and Costanza, 1998; Klaphake et al., 2001).

The concept of a catchment as a basic management unit, implies certain geographical characteristics, such as topography, that delimit the area not only with respect to water, but also with respect to other media flows, such as energy, material and information. The flow of water serves as an indicator of the relief and landscape characteristics, on the one hand, and as an integrator of many of the processes occurring within the catchment, on the other. The catchment boundaries may influence local atmospheric transport and local climate, migration flows and the associated patterns of species distribution, as well as dispersion flows of pollution. The quantity and quality of water serves as an indicator of the relief and landscape characteristics, on the one hand, and as an integrator of many of the processes occurring within the catchment, on the other.

The use of the catchment as a management unit may also account for other factors, both of ecological and social origin. Historically human settlements have tended towards sources of water—in southern Africa, these are most often rivers. Consequently, much of the human population and the associated anthropogenic pollution, and other forms of environmental stress are often tied to the river network. The assumption that the catchment offers an optimal spatial scale for the management of ecosystems, may not necessarily be valid, however, it has become accepted that catchments offer a good compromise as a spatial unit on which to focus management strategies.

The hierarchical structure of catchments, sub-catchments and sub-sub-catchments is very useful for upgrading or downgrading scale, "zooming" in and out, changing resolution, depending upon the type and scale of the managerial problems to be resolved. Furthermore, the view of a catchment as a hierarchy of nested sub-catchments is compatible with the view of an ecosystem as a hierarchy of nested smaller ecosystems.

In the past, South African approaches to water resources management have followed a typical command and control type approach where focus has been on controlling the hydrological cycle, largely through construction of dams, in order to harvest its goods and services, and reduce its threats, and thus produce predictable outcomes. It has been noted that this type of top–down approach to management of natural resources inevitably results in a reduction in the natural range of variation of ecosystem properties and processes and a resulting decline in both the services provided, and the resilience of the system (Holling and Meffe, 1996; Rogers et al., 2000).

Furthermore, aspects of the system where quantitative understanding is relatively poor, such as ecological functioning, may have largely been ignored in the decision-making processes. This may have been due no less to the ability of scientists to understand and predict such interactions, than the ability or willingness of policy makers and planners to accommodate ecosystem dynamics, especially, when expressed by non-quantitative means.

The management of water resources solely to maximise consumptive use has been giving way to a realisation that management for environmental values, such as biodiversity, and social and cultural values is necessary (Cortner and Moote, 1994). This is typical of the change in the way that natural resources are now attempted to be managed; a fundamental shift from, in this case, water resources management performed by a single statutory organisation, possibly based on static information from a large systems analysis type of simulation model, to an approach to management that recognises the importance of the stakeholders, including the environment in the process and the inevitability of change and uncertainty.

In the ecological field, this shift in the management approach found expression in the form of "adaptive management" (Holling, 1978) which has been widely advocated as the paradigm which natural resource managers should adopt. It is built on a recognition that ecosystems are complex systems, which are "adaptive", or "self organising" and that management systems must be able to adapt to change or surprise in the system. In this context management must be both anticipatory and adaptive (Kay, 1997). In South Africa, the promulgation of a new National Water Act (NWA) in 1998 created an enabling environment for an ecosystem approach to management of water resources. Guidelines being developed for the implementation of the NWA show that adaptive management concepts are becoming embedded in South African water resources management approaches, although some have cautioned that the rush to implement the Act could lead to these principles being compromised (Rogers et al., 2000).

3.2. Ecosystem services and the hydrological cycle

Water is fundamental to life on land as well as in lakes, rivers, and other freshwater habitats. However, renewable freshwater comprises only 0.26% of global water. Traditionally, humans rely on renewable fresh water for drinking, irrigation of crops, and industrial uses as well as the production of fish and waterfowl, transportation, recreation, and waste disposal. Growth in population, increased economic activity and improved standards of living have led to increased competition for and conflicts over this limited fresh-water resource (Gleick, 2000). Often this results in a focus on the development of structures to provide increased volumes of fresh water and other artificial benefits.

This contributes to an argument that our perspective of the hydrological cycle has become typically reductionist, i.e. we have been considering the hydrological cycle purely in terms of simplified representations of mechanical interactions between the components of the system. However, associated with the development of the ecosystem approach, and a focus on the goods and services provided to society from ecosystems, there has been an associated rediscovery of the hydrological cycle.

As water moves downstream through the landscape, it is used along the way to support ecosystems and maintain their functioning. In return for this expenditure of water, the hydrological and biological processes of the ecosystem results in the generation of various goods and functions that may be utilised by communities throughout the catchment (McCartney et al., 2000). In this regard, freshwater ecosystems may be considered as structured, four-dimensional systems in which the spatial patterns of environmental variables and biological populations are determined by longitudinal, lateral, vertical and temporal gradients, interconnected by fluxes of water, energy and materials.

When considering the provision of goods and services provided by the hydrological cycle, it is useful to distinguish between movement of water vapour as opposed to liquid water. Recent literature on water and food production often refers to water vapour and liquid water as green water and blue water, respectively (Falkenmark et al., 1999; FAO, 2000). Blue water is the runoff originating from the partitioning of precipitation at the land surface (forming streamflow) and the partitioning of soil water (forming baseflow and groundwater recharge) (Fig. 2). Green water is represented by water vapour and is represented by the flow of water to the atmosphere as evapotranspiration (ET), which includes transpiration by vegetation and evaporation from soil, lakes, and water intercepted by canopy surfaces (Rockström et al., 1999).

Increasing attention is now being paid to understanding the dynamic interrelationships between "green" and "blue" water, as these are considered to underpin essential terrestrial and aquatic ecosystem services (Falkenmark et al., 1999; FAO, 2000). The Food and Agriculture Organization (FAO) suggests that almost all "green" water and a large proportion of "blue" water is needed to sustain ecosystem structures and functions, and maintain sustainable water supplies (FAO, 2000). The movement towards specifying instream flow requirements in many countries arises from the recognition that not all "blue" water should be considered to be available for direct use by society; a proportion must always be reserved for ecosystem functions (Falkenmark et al., 1999; FAO, 2000). Ecosystem services most commonly associated with green water are the production of biomass resulting from the movement of water through agricultural crops and timber by transpiration. Thus, water constitutes an essential building block in all terrestrial production, and also sets the ecohydrological conditions for biological diversity in any habitat (Rockström et al., 1999).

The role of land use in the catchment is of critical importance in this regard. The land use in a catchment partitions rainfall between water vapour flows to the atmosphere as evaporation and transpiration (green water), and flow of water to rivers and to groundwater (blue water). Thus, the water passing through a catchment is highly sensitive to its land use and IWRM must therefore, consider the management of the land portion

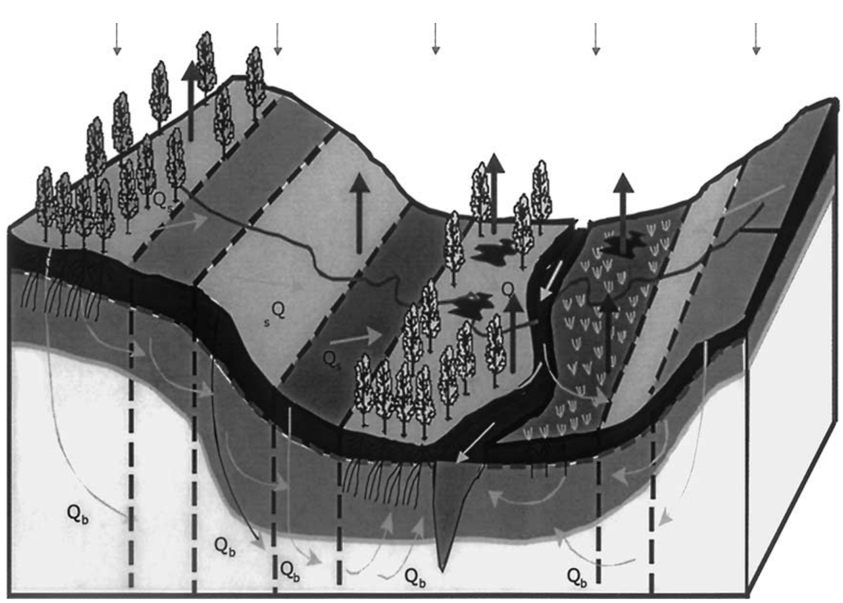

Fig. 2. Movement of water through the landscape.

of the water resources system as critical to its success. The role of land use and change in land use in a catchment is highly complex. Land use changes may be gradual conversions (e.g. gradual invasion of exotic species) to total modifications (e.g. conversion of grasslands to forest plantation). In addition, there are structural complexities between different land uses, and functional complexities within them, all of which influence the movement of water through the landscape. However, there is often a dichotomy between land use and water resources considerations. Even in important policy documents such as the United Nations Commission on Environment and Development Agenda 21, sections on land use and freshwater show little appreciation of water related phenomena as determinants of land use, or of land use practices as determining water pathways, water flow and water quality (Falkenmark et al., 1999).

Thus, in the context of this paper, the perspective of McCartney et al. (2000) is adopted, and freshwater ecosystems are considered as linked landscape elements that affect the passage of blue water from the land to the sea and green water from the land to the atmosphere. Almost the whole of the terrestrial milieu is considered as part of freshwater ecosystems and encompasses all the environmental units associated with river catchments, including the whole length of the river channel, lakes, pans, wetlands as well as the upland areas which drain into these—in many instances the river catchment is the most easily identified management unit.

4. Sustaining the resource base

The South African NWA considers aquatic ecosystems to be the base from which resources are derived and without which attaining the goals of equitable access to water and societal development is not possible (DWAF, 1997). Consequently, the water resource has been defined as an ecosystem which includes the physical or structural aquatic habitats (both instream and riparian), the water, the aquatic biota, and the physical, chemical and ecological processes which link habitats, water and biota (MacKay, 2000). This definition is clearly compatible with the ideas proposed by Rockström et al. (1999) as presented in the preceding section of this document.

The move to integrated management of water resources, on an ecosystem basis has led to the introduction of a new set of tools for water resource management in South Africa. These have been developed according to the concept that there is a degree of utilisation which can be sustained by a water resource before resilience is lost. Resilience in turn depends on maintaining a certain base level of ecological integrity and function. This level is referred to as the ‘‘resource base’’ and it is considered that its protection is dependent upon the quantification of a reserve for the water resource as well as the management of water users in order to meet the reserve (MacKay, 2000; Mackay, 2001). This approach to water resources protection is based on the development of tools to serve the following:

- Resource directed measures that focus on the water resource as an ecosystem and set clear objectives for the desired level of protection of that resource through a classification system, determination of the reserve and setting of resource quality objectives.
- Source directed controls which include a wide range of regulatory measures that are intended to control the sources of impacts on water resources such that the objectives for resource protection are achieved. These include waste standards, licensing of water users, etc. For example, commercial afforestation in South Africa has been controlled since 1971. This has been achieved, firstly by a so-called ‘‘permit system’’ and now by the declaration of forestry as a streamflow reduction activity (SFRA). Under both systems, a water use license is required. In some regards, this could be considered an ecosystem management tool which considers the linkages between terrestrial vapour flows (i.e. transpiration and biomass production by trees) and streamflow. However, the somewhat misleading focus on streamflow in the declaration of SFRAs does little to promote this concept.
- Demand management initiatives in order to keep utilisation within the limits required for protection.
- Continuous monitoring of the status of the country’s water resources to ensure that the resource quality objectives are being met.

This is reliant upon the development of methodologies and procedures to achieve these, and is currently a major focus in South Africa. These methodologies should be flexible, protective and should consider extremes, both in socio-economic conditions, and in natural variability of components of the hydrological cycle. In their current state, these can be considered as macro-level approaches to the development of management plans, despite the intention that these will be developed in more detail as the need arises through the identification of priority catchments. It is in the development of these methodologies that theory and philosophy need to become practice, and it in their design and implementation that addressing the aforementioned gap between these is critical. Recent workshops on the design and implementation of such tools, including RDMs and SFRAs, have highlighted some major differences of opinion between scientists, catchment stakeholders and water resource managers (at this stage, represented by the Department of Water Affairs and Forestry

(DWAF)). Clearly, great difficulties are being experienced by the organisations and individuals involved in bridging this gap, with the resulting danger that managers will resort to traditional command and control approaches to management of the water resources system, albeit under the banner of IWRM. This has been referred to as "roll back" by Rogers et al. (2000), who also offer some profound recommendations on the complicated issue of implementing the ecosystem approach through adaptive management.

It has been suggested that the proposed resource classification system will create a means of resolving some of these issues by providing for an intersection of ecological and societal values. The classification system will provide for management of the ecosystem based on human (manager, stakeholder, and scientist) judgements as to which ecosystem goods and services, both natural and artificial, should be harvested from those systems. It is to be expected that in the development of this classification system "reasonable people will differ" (Levin, 2001).

One problem of particular concern raised by Rogers et al. (2000), is that the protection of the water resource and thus management of the Reserve, could be implemented merely through the control of the number of water use licences granted. They warn that simply limiting the use of water through this type of "command and control" licensing does not constitute an ecosystem approach. This is a valid concern and related to this is the question as to whether focus on the Reserve and the current macro-level approach to licensing of water uses will adequately consider the utilisation of green water?

Monitoring of the response of components of the aquatic ecosystem to natural and man-induced changes is an imperative of the ecosystem approach. A critical concern is how to most effectively design a monitoring programme for a broad enough range of indicators at adequate spatial temporal scales of biodiversity and ecosystem integrity as a management tool to ensure sustainability of natural resource systems (Rogers and Biggs, 1999). To some extent, monitoring programmes are being devised with adaptive management approach that recognise that the system being monitored is dynamic and variable. Some indicators are selected to represent a wide range of scales, but the focus is on relatively fine scale indicators, such as specific species at specific sites. Furthermore, the indicators selected are largely collected within rivers. Similar to the problem of attempting to sustain ecosystem integrity through the issuing of licenses for water use, "blue water" indicators, including water quality indicators, are an indirect and delayed reflection of catchment condition. Monitoring programmes should also include direct indicators of catchment condition, such as remotely sensed land use assessments.

5. Discussion and conclusions

Considerations of an ecosystem approach to IWRM and the role of the hydrological cycle highlight the dependence upon the movement of water across and between interfaces at a wide range of spatial and temporal scales. Macro-level planning does not allow for adequate consideration of processes and linkages at different levels essential for the provision of goods and services which result from effective functioning of the hydrological cycle. "Old style" management of water resources was unable to account for this complexity and often resulted in the loss of ecosystem services which arise from the interactions at these levels.

Furthermore, broad levels of assessment do not consider the implicit hierarchical nature of both ecosystems and the hydrological cycle and the associated understanding that sustainable use of these systems depends adequate functioning at all levels of the hierarchy. The removal of one level will ultimately result in the failure of the system as a whole. It must be accepted that the relationship between the hydrological cycle and the provision of goods and services associated is highly complex and will never be fully understood. Traditional approaches to water resources management have tended to oversimplify the hydrological cycle. Consequently, management options have focussed on the provision of a few of the most obvious of these and the control of the hydrological cycle to provide specific artificial services. This has been exacerbated by the ability of a few powerful stakeholders to influence the decision-making process in their favour. Political and social considerations tend to override scientific recommendations, especially where there these are considered to be vague or unquantifiable. Although decision makers and planners need to devote a great deal of effort to ensuring that the system is managed at levels that guarantee optimal exploitation rates (De Leo and Levin, 1997), they must recognise that ultimately, sustainability must "emerge from the democracy of distributed responses and competitive renewal, and not from system-level regulation at constant normative levels" (Levin, 2001).

The movement to IWRM, provides the opportunity to consider the complexity of the hydrological cycle more fully. However, there is a danger that the rush to implement the new NWA in South Africa and the pressure applied by lobby groups, will once again lead to an oversimplification of the hydrological cycle. In particular, there is a danger that IWRM tools will be applied in a such a way that that they will allow a level of degradation beyond that from which the ecosystem is able to recover i.e. beyond the level of its resilience.

Despite the pressure for implementation, it should be remembered that the NWA allows for its implementation in a "phased and progressive" manner. Therefore, institutional capacity building must be an integral part of ecosystem management strategies. Despite the conceptual goal of an holistic management strategy involving all role-players, it is necessary to start in the framework of existing institutions and adopt a pragmatic and at times even piecemeal approach. Scientists and managers involved in enabling the NWA, need to ensure that these structures and tools are consistent with the goal of sustainability.

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