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Ecosystem-based River Basin Management: its approach and policy-level application†

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Abstract:

Integrated Water Resources Management is an approach aimed at achieving sustainable development with a focus on water resources. This management concept is characterized by its catchment approach, inter-sectoral and interdisciplinary approach and multiple management objectives. There is an effort to widen the management scope to include multiple resources and environmental considerations in the river basin management schemes. In order to achieve river basin management objectives and multiple global environmental benefits, an ecosystem approach to river basin management is promoted. The Ecosystem-based River Basin Management aims to maximize and optimize the total value of the ecosystem functions relevant to classified ecosystems within a river basin by conserving and even enhancing these functions for the next generations. A procedure to incorporate such ecosystem functions into policy framework is presented in this paper. Based on this policy framework of the Ecosystem-based River Basin Management, a case study is introduced to apply the concept to the Yangtze River basin. According to the United Nations Environment Programme (UNEP) assessment report, this basin suffers from frequent floods of large magnitudes, which are due to the degradation of ecosystem functions in the basin. In this case, the government of the People's Republic of China introduced Ecosystem Function Conservation Areas to conserve ecosystem functions related to flood events and magnitude, such as soil conservation, agricultural practices and forestry, while producing economic benefits for the local population. Copyright © 2003 John Wiley & Sons, Ltd.

KEY WORDS integrated approach; river basin management; ecosystem approach; ecosystem functions; ecosystem services; policy application

SUSTAINABLE DEVELOPMENT AND INTEGRATED APPROACH TO WATER RESOURCES MANAGEMENT

At the United Nations Conference on Environment and Development (UNCED) in 1992, the 'sustainable development' concept was endorsed as the guiding principle for economic development and environmental management. The Bruntland Commission's *Our Common Future* (WCED, 1987) emphasized that sustainable development focuses on meeting the needs of both current and future generations. Based on the understanding that the resources utilized by human beings are limited, and that the environment cannot be degraded at the sacrifice of its benefits and the health of human beings and the ecosystems on Earth, 'sustainable development' is interpreted as a concept aimed at achieving both social and economic development while maintaining environmental quality. This is also based on the understanding that human society and the natural environment constitute a complex system of interacting components (political, cultural, social and environmental components), and one component has impacts on others over time. Conventionally, in addressing issues and problems in each component of this system, sectoral approaches are adopted. One such example is that irrigation water is dealt with by the agricultural sector, while the overall water allocation and quality maintenance is conducted by the water resources sector. Therefore, if one is to address issues and

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problems in one component of the system, this implies that other components need to be managed together, eventually leading to the need for a cross-sectoral institutional arrangement.

Such sustainable development issues have been strongly argued in the field of freshwater (or inland water) resources. Freshwater consists only 2·53% of the waters on the Earth's surface, and most freshwater on Earth is locked in icecaps, permafrost and glaciers (1·74%) or deep in groundwater (0·76%) (Shikolomanov, 1993). Therefore, only a small portion of the Earth's freshwater can be readily available for human use. Furthermore, the available freshwater is temporally and spatially unevenly distributed, preventing timely and effective use of water resources on a local scale. It is pointed out that this uneven distribution of freshwater resources may become more and more pronounced, not only by unevenly distributed population growth, but also due to global environmental changes, such as global warming and the degradation of land and vegetation. According to UNEP (2000), approximately 20% of the world's population lacks access to safe drinking water and about 50% lacks adequate sanitation. By the year 2025, as many as two-thirds of the world population may be subject to moderate to high water stress (WMO, 1997). This situation will become more serious if the global population continues to grow at the current pace. Further, global climate change and associated environmental changes, including more extreme hydrological events that are predicted, are estimated to lead to more uneven distribution of freshwater resources. International environmental issues that emerged around the time of UNCED, such as biodiversity, desertification and climate change, which are covered by the so-called 'Rio Conventions', are also interlinked with the quality and availability of water.

Conventionally, efforts were made for control and management of resources targeting the water bodies and water courses themselves, such as structural flood control measures, and reducing direct end-of-the-pipe discharge of industrial and municipal wastewater. However, it is now well recognized that land-based human activities and natural events in the hydrological, geochemical and ecological cycle within river basins influence the availability and quality of inland water resources. As such, basin management for the ultimate purpose of controlling quality, availability of and demand for inland water resources addresses natural events and human activities within target basins. Unfortunately, however, the fact is that within one basin, various factors, including hydrological, geochemical, biological or socio-economic (and even political and cultural) factors, constitute a complicated system of interlinkages relevant to water quality and quantity, and this makes basin management difficult to design. To make the situation even more complicated, water managers usually set multiple objectives for the use of the available and limited freshwater resources. At the same time, different management objectives by various sectors in many cases conflict with each other, and, therefore, an institutional coordination mechanism is needed to achieve these objectives effectively.

In order to achieve sustainability for water resources management, and also based on the concept of interacting human and natural systems, Agenda 21 Chapter 18 lists, as its first component, the 'integrated water resources development and management' (UN, 1993). Like the concept of sustainable development, which is interpreted differently by many, the 'integrated water resources management' concept was also interpreted differently by many water researchers and managers. Looking at the history of the development of the water management concept, as above, water resources management turned its focus from single-purpose water resources management to multiple purpose and multiple disciplinary management. Further, the management approach has been changed from water course/body management to 'catchment' or 'watershed' management. 'Integrated Water Resources Management' is considered to be characterized by three distinctive components: catchment approach (in the case of groundwater, 'aquifer' management), interdisciplinary and inter-sectoral institutional arrangements (and wider stakeholder participation), and multiple management objectives. However, it is noted that Integrated Water Resources Management still targets a single resource—water (or more accurately, inland water) with multiple uses. The management goals are associated with increasing water availability (by supply and demand management) for human use (recently with focus on maintenance of ecological functions) and water quality. This characteristics of Integrated Water Resources Management are in sharp contrast with 'Integrated Coastal Area Management', which aims at multiple resource and multiple use management based on physical planning and resource management for the coastal strip and waters (UNEP/MAP/PAP, 1999).

In order to promote the concept of Integrated Water Resources Management and to present programmatic and strategic approaches, the United Nations Environment Programme (UNEP) launched a freshwater programme, known as the Environmentally Sound Management of Inland Waters (EMINWA) programme, in 1986. This programme is designed to assist governments to integrate environmental considerations into the management and development of inland water resources, with a view to reconciling conflicting interests and ensuring the regional development of water resources in harmony with the water-related (natural and human) environment throughout entire water systems (Dávid *et al*., 1988). Its objectives are defined as follows:

1. Assist governments to develop, approve and implement environmentally sound water management programmes for inland water systems and to use this approach for demonstration purposes elsewhere.
2. Train experts and establish training networks in developing countries to implement environmentally sound water management programmes, including drinking water supply and sanitation programmes.
3. Prepare a manual of principles of and guidelines for the environmentally sound management of inland water systems.
4. Make regular worldwide assessments of the state of the environment for inland water systems.
5. Inform the mass media of the achievements and activities of the programme and to increase public awareness of environmentally sound water development (Dávid 1986).

To achieve these objectives, a three-tier approach has been taken:

1. Development of a diagnostic study on the environmental status and problems on a river basin scale (this also furthers awareness of various stakeholders involved in the environmental management of the river basin).
2. Based on the identified environmental priority problems, development of a basin-wide action plan in order to address the problems identified and prioritized. This action plan is aimed at incorporating the environmental situation into water management schemes and at achieving the sustainable development of the target river basin.
3. Implementation of the developed action plan by coordinating various sectors and garnering international support.

Initially placing emphasis on internationally shared river/lake basins, UNEP applied this approach to the Zambezi River basin (shared by Mozambique, Malawi, Zambia, Zimbabwe, Botswana, Angola, Namibia) and the Lake Chad Basin (shared by Algeria, Sudan, Central African Republic, Chad, Niger, Nigeria and Cameroon, but the project targeted the conventional basin, shared by Chad, Niger, Nigeria and Cameroon). In addition, diagnostic studies were prepared for the Aral Sea basin (shared by Kirgiz, Kazakhstan, Uzbekistan, and Turkmenistan), the Mekong River basin (shared by China, Myanmar, Vietnam, Cambodia, Thailand and Laos), North Xinjiang (in the People's Republic of China), the Lake Erhai basin (in the People's Republic of China), the San Juan River basin (Costa Rica and Nicaragua) and the Lake Titicaca basin (Bolivia and Peru).

INTEGRATED RIVER BASIN MANAGEMENT

With the progress made in research on development and the environment, it is now widely recognized that almost all socio-economic sectors directly affect the environment and are affected by changes in environmental conditions. Global climate change, associated with energy production and transportation, and further with human consumption patterns, affects precipitation patterns and water balance (Gleick and Adams, 2000; IPCC, 2001) and water quality parameters, such as algae content, which is affected by ambient temperature. Water scarcity and quality degradation cause aquatic biodiversity loss. Degradation of land and vegetation-cover changes the hydrological and geochemical cycle, causing changes in run-off and sedimentation patterns.

Therefore, in association with meeting the water-related management needs, under the concept of integrated environment management, other resources will need to be managed, so that management efficiency and cost effectiveness may be enhanced and multiple benefits achieved. With these emerging environmental concerns, water resources management now needs to be effectively coordinated with other resource management needs and objectives, such as in forest management (e.g. in terms of carbon sink and biodiversity consideration), renewable energy production (e.g. in terms of greenhouse gas emission reduction) and land-use planning (e.g. in terms of soil erosion control). In order to achieve an efficient and effective means of natural resources and environmental management, an approach of multiple resource management targeting river basins is considered to be the basis for achieving multiple environmental and resource benefits for human beings and ecological functions. Considering the crucial role of water in the environmental processes and human life, water resources remain to be central to this approach, and the threads to link with other resources and human activities, thus justifying the management unit of river basins. To indicate such an approach, distinguished from the single-resource, multiple-use Integrated Water Resources Management, the term 'Integrated River Basin Management' is used in this paper, although this definition and distinction are not widely accepted.

In order to promote the concept of the Integrated River Basin Management and to present programmatic and strategic approaches, UNEP developed a programme called Integrated Coastal Area and River Basin Management (ICARM). While ICARM aims to integrate river basins and coastal areas into one management unit based on their hydrological, geochemical, ecological and socio-economic linkages, it basically takes an approach of coordination of multiple resource management and sectors. The programme was built on the freshwater-related EMINWA programme and the coast-related Regional Seas Programme of UNEP.

UNEP and Priority Actions Programme Activity Centre (PAP/RAC) of the Mediterranean Action Plan have jointly prepared the 'Conceptual Framework and Planning Guidelines for Integrated Coastal Area and River Basin Management' (UNEP/MAP/PAP, 1999). These guidelines include a proposed conceptual planning process for ICARM, and promote, among others, participation of different levels of stakeholders in this process and use of strategic economic and environmental impact assessment. UNEP is applying this ICARM approach to a set of demonstration sites: the Cetina River basin and its associated coastal areas between Croatia and Bosnia and Herzegovina (UNEP/MAP/PAP, 2000); Senegal River basin and its associated coastal areas in Senegal (UNEP/DHI/SGPRE, 2002); and four demonstration sites in Southeast Asia (UNEP/CIRAD/CORIN, 2001).

The basic principles of Integrated Water Resources Management or Integrated River Basin Management appear to be understood and accepted. However, an actual model to present successful results of integrated approaches has yet to be presented. The Global Environment Facility (GEF), in its International Waters portfolio, has developed an integrated approach to addressing transboundary issues to achieve global and regional environmental benefits. The main approach for its projects is to develop a Transboundary Diagnostic Analysis (TDA) to pinpoint transboundary environmental issues and hot spots, and to conduct a causal chain analysis. The TDA is followed by a Strategic Action Programme (SAP), which presents a set of remedial measures to address identified environmental issues and hot spots.

Despite the efforts of various international organizations, such as GEF and Global Water Partnership (GWP), operational methodology for Integrated River Basin Management or Integrated Water Resources Management appears yet to be developed. The Ecosystem-based River Basin Management is an approach to achieve the goals of the Integrated River Basin Management through the thread of the 'ecosystem approach' and 'ecosystem functions'.

ECOSYSTEM CONCEPT AND APPROACH

An 'ecosystem' is defined as a 'dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit' (Convention on Biological Diversity). UNEP/IUCN (2001) defines the ecosystems as those composed of a number of physical, biological and chemical components, such as soils, water, plant and animal species and nutrients. According to such a definition, the ecosystem refers to system processes rather than spatial areas, and the system and its functions and processes can be defined at a range of spatial scales.

The scientific understanding of an ecosystem approach encompasses (UNDP (United Nations Development Programme)/UNZP/World Bank (WB)/WRI (World Resources Institute), 2000):

- recognizing the 'system' in ecosystems, respecting their natural boundaries and managing them holistically rather than sectorally; and
- regularly assessing the condition of ecosystems and studying the processes that underlie their capacity to sustain life so that we understand the consequences of our choice.

The political understanding of the approach encompasses:

- Demonstrating that much can be done to improve ecosystem management by developing wiser policies and more effective institutions to implement them;
- Assembling the information that allows a careful weighing of the trade-offs among various ecosystem goods and services and among environmental, political, social and economic goals; and
- Including the public in the management of ecosystems, particularly local communities, whose stake in protecting ecosystems is often greatest.

The biotic and abiotic components (organism, soils, water, atmosphere, etc.) interact with each other, and these interactions are perceived as processes in the biological, geochemical, physical and hydrological cycles (Figure 1). When specific functions in the system are deemed to be useful to health, safety and welfare of human beings and human productive activities, these are considered to be 'ecosystem goods' and 'ecosystem services'. Ecosystem attributes, such as cultural uniqueness/heritage, biological diversity are also considered valuable functions for human beings.

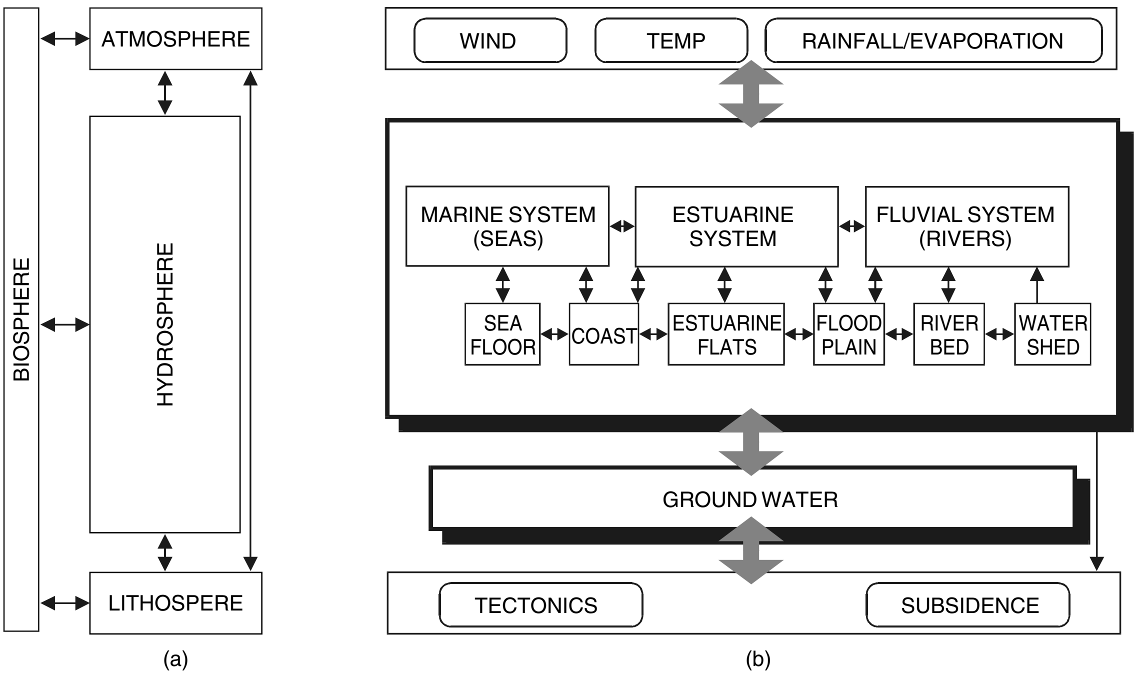

Figure 1. (a) Generic system diagram of the natural components. (b) Elements of the abiotic component (UNEP/MAP/PAP, 1999)

ECOSYSTEM-BASED RIVER BASIN MANAGEMENT

The main objective of the Ecosystem-based River Basin Management is to achieve multiple river basin management goals, and at the same time to maximize and optimize an array of ecosystem functions, particularly the ecosystem goods and services, by conserving and enhancing these functions for the next generations. Emphasis is placed on the use of ecosystem functions for human benefits, while preserving such ecosystem functions, and realizing economic development across all relevant sectors without conflicting with ecosystem functions. Through this management approach, the idea is to have a harmonized economic development, without hampering ecosystem functions, meaning that the approach endeavours to achieve sustainable livelihood utilizing ecosystem services and goods.

Under the Ecosystem-based River Basin Management, management goals can be set for specific water-related issues, but can also address other ecosystem components within a target river basin simultaneously, such as terrestrial biodiversity and agricultural production within that basin. In addressing existing environmental problems and hot spots, the approach can aim at enhancing the total capacity or resilience of the ecosystem functions, including the capacity to receive environmental pressure and perturbation, in contrast to the traditional river basin management, which aims at adopting remedial measures to existing environmental problems. The approach is synonymous to enhancing human immunity to any possible diseases, in contrast with chemical and biological remedial measures to diseases. Such an approach does not necessarily prevent management efforts combined with traditional engineering methods, such as construction of dams. In some cases, engineering measures may enhance ecosystem functions that can lead to mitigation of environmental problems. The Ecosystem-based River Basin Management shares a similar scientific basis as 'Ecohydrology' promotes (Zalewsky, 2000), but it clearly intends to provide a policy-level methodology incorporating such an ecosystem approach in river basin management.

Since an ecosystem is a functioning system rather than geographically defined space, ecosystem functions are scale specific. This means that a river basin as a whole can be considered to be a functioning system, and, at the same time, a forest area included in this river basin is also considered to be a functioning system, depending on what management objectives are set. When the whole river basin is considered to be an ecosystem for management purposes, relatively larger scale ecosystem functions (such as the water retention capacity of the basin, compared with smaller scale forest hydrology) are pronounced and considered. At the same time, it is also possible that the whole river basin can be divided into specific ecosystems, each of which has unique and system-specific functions.

Many river basin managers are taking the approach of considering the whole river basin as one ecosystem, but such an approach appears to have disadvantages when attempting to conserve and/or enhance individual functions that are unique to subsystems in the river basin. In Ecosystem-based River Basin Management, the whole river basin is divided into the following ecosystems, based on the classification of UNDP/UNEP/WB/WRI (2000):

- agroecosystems
- forest ecosystems
- freshwater ecosystems, and
- grassland ecosystems.

UNDP/UNEP/WB/WRI (2000) also lists coastal ecosystems. Although the relationship between freshwater flow and material transport with coastal ecosystem conditions is important (UNEP/MAP/PAP, 1999), this ecosystem is not considered in this paper in order to highlight the focus on inland water systems. Further, Mountain Ecosystems, Polar Ecosystems and Urban Ecosystems, also referred to as ecosystems, are not considered.

Each of these ecosystems included in a river basin can have many types of functions, uses and attributes that can provide a valuable contribution to achieving management goals and objectives for river basin management, for the ultimate purpose of benefiting human life and socio-economic development. In order to maintain ecosystem integrity and to achieve wise and maximum use of a range of ecosystem functions, it is proposed that a set of multiple objectives for ecosystem management be established, following the framework of the Integrated River Basin Management. For this purpose, the following procedure is proposed (modified from Nakamura (2001)):

1. Classification and inventory of different ecosystems.
2. Identification and assessment of ecosystem functions in each categorized ecosystem.
3. Rapid or full quantification and economic valuation of the ecosystem functions.
4. Official recognition of the ecosystem functions and their values.
5. Preliminary identification of Integrated River Basin Management objectives, including use and management of multiple resources.
6. Trade-offs between the ecosystem functions identified and between the ecosystem functions and the Integrated River Basin Management priorities.
7. Clear statements of management objectives for wise and maximum use of ecosystem functions identified and recognized.
8. Increased awareness of the ecosystem functions.

More concretely on each step:

1. At the first step, the target river basin is classified into different ecosystems: agroecosystem; forest ecosystem; freshwater ecosystems; and grassland ecosystems. Based on the division of the basin into the ecosystems, an inventory of important ecosystems will be prepared.
2. In the identification and assessment of different ecosystem functions, it is important to see both the present functions and the prospective changes in these functions in the future due to natural and human pressures. In order to incorporate the ecosystem approach successfully into river basin management policies, it is important to identify generic qualitative ecosystem functions that are included in river basins.
3. Quantification and valuation of ecosystem functions usually requires extensive ecosystem monitoring and research, at least over a certain duration of time. Except for limited important ecosystems, such monitoring or research has not been conducted to provide reliable data, or monitoring and research was not conducted within the overall framework of integrated ecosystem assessment, so that comprehensive and compatible information or data has not been obtained. Despite the general difficulties in quantification and economic valuation of ecosystem functions, there are a number of methodologies attempting to do so in a rapid fashion. In the case of wetland functions, there are several methodologies for rapid assessment: (Adamus *et al*. (1987) for the Wetland Valuation Technique (WET); Maltby *et al*. (1994) for the Functional Analysis of European Wetland Ecosystems (FAEWE); and James (1991) for wetland valuation guidelines). In many cases the quantification and valuation of ecosystem functions is not possible, and it is proposed that ecosystem function 'indicators' or 'indexes' be adopted. By identifying indexes or indicators, it is easy to set the relative importance of certain functions in river basin management schemes, and to monitor chronological changes in the functions.
4. The identified, rapidly assessed and valued ecosystem functions should be presented to a wide range of stakeholders involved in river basin management and relevant productive activities within the river basin. The objective of such stakeholder consultation is to make clear what functions are beneficial to which group of stakeholders in which part of the river basin. Through stakeholder consultation, governmental bodies responsible for river basin management should and can clearly recognize the ecosystem functions that should be utilized for the overall management goal of the target river basin.
5. Before conducting trade-off analysis, preliminary river basin management objectives are set. The procedures for setting management objectives can be established, following integrated river basin management guidelines, such as the ICARM guidelines.

6. There are normally conflicts between conservation and enhancement of specific ecosystem functions and management of the related human activities (such as construction of dams, land-use planning and changes, etc.), and between some ecosystem functions and others. Therefore, under an overall management framework, there must be an analysis of trade-offs (Figure 2). Through trade-off analysis, clear management

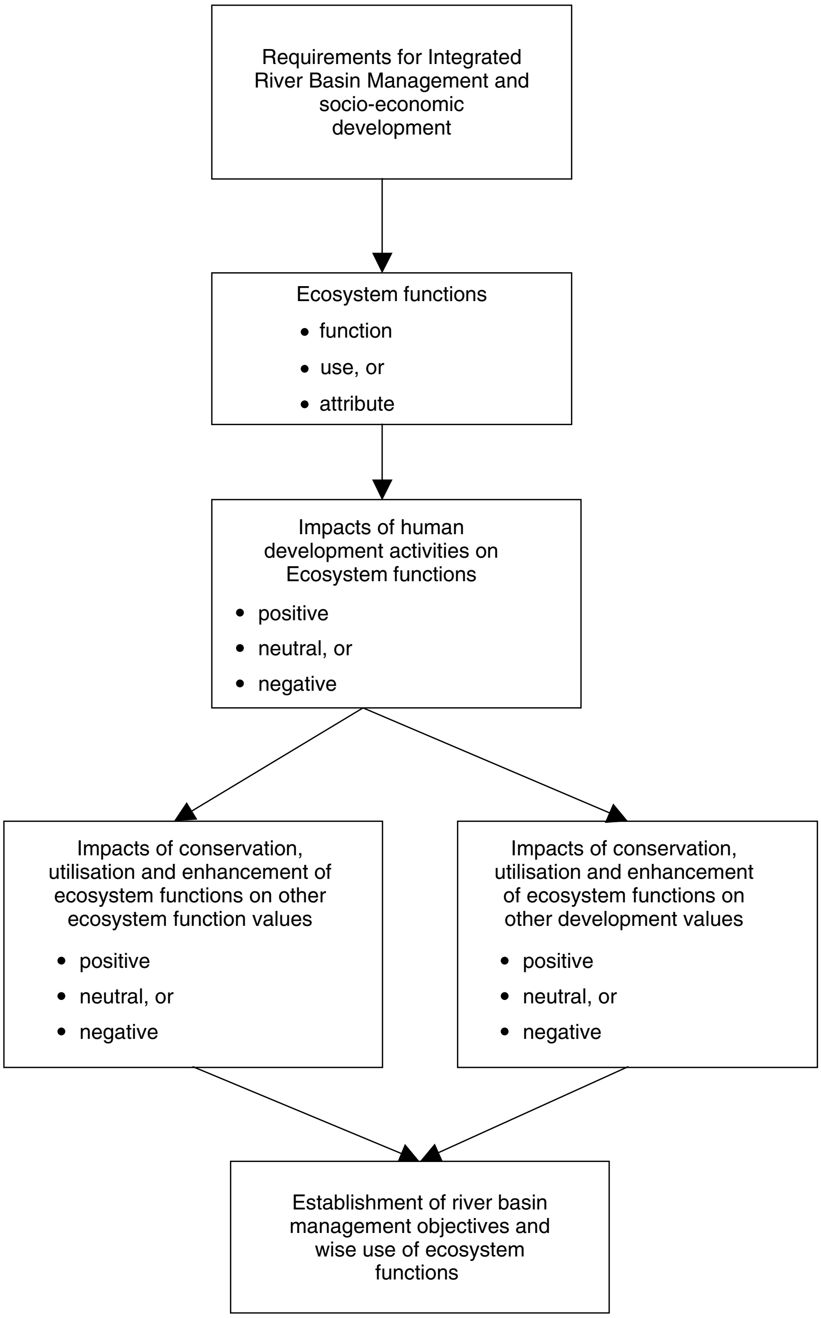

Figure 2. Trade-offs between ecosystem functions and between ecosystem functions and management and development objectives (modified from Ritchie and James (1997)

objectives can be set as to how specific ecosystem functions can be utilized, conserved and enhanced, in order to maximize and optimize the overall value of ecosystem functions.

7. The governmental body responsible for river basin management, based on the results of the stakeholder consultation, should clearly state the management objectives of the river basin and how the ecosystem functions in the river basin should be utilized, conserved or enhanced under the management objectives.
8. However, the official statement itself does not necessarily mean that ecosystem functions can be well incorporated into various sector plans. It is important that awareness should be raised on the role of the ecosystem functions among various sectors and stakeholders directly involved in sectoral activities.

Under this integrated approach, the issue is how to assess and evaluate values of ecosystem functions, which are recognized differently by varying levels of stakeholders. Such values can be created as functions of various ecosystems, and, therefore, it is proposed to set a management goal and objective of maintenance of, and wise and maximum use of, ecosystem functions, for the purpose of mitigating conflicts over specific resources in the ecosystem. In particular, for the productive systems, sharp conflicts over evaluation of resource values are likely to occur, because some ecosystem functions are deemed to have high economic values. This ecosystem approach requires recognition and endorsement of the ecosystem functions among stakeholders at differing levels, thus necessitating participation of a wide range of stakeholders.

ASSESSMENT AND VALUATION OF ECOSYSTEM FUNCTIONS

In the process, difficulties relating to how to identify, assess and economically evaluate ecosystem functions are encountered. Table I shows a list of examples of freshwater ecosystem functions and actual examples found in wetlands in Asia and the Pacific.

Table II shows a list of classified services provided by freshwater ecosystems (drawn from IUCN (2000)).

Following the examples of freshwater ecosystem functions, functions of other ecosystems within a river basin can be listed. Once generic lists of ecosystem functions are developed, they would help planners and managers to identify and assess ecosystem functions.

These functions may or may not be easily evaluated in monetary terms. For example, flood control function of an aquatic ecosystem can be valued in terms of potential flood damages to human properties and life. However, groundwater recharge functions of wetlands are vital to freshwater resource users, and economic valuation of such a function would require valuation of groundwater resources for all users, and would be difficult to conduct.

Where strict assessment and valuation is not possible, indicators or indexes (a composite of indicators) that represent relative rather than absolute values of ecosystem functions are used. The purpose of developing indicators is to present relative values of ecosystem functions associated with specific components in the system in order to provide guidance on what functions are to be conserved, utilized or enhanced, where in the basin they are, and for the benefit of which sector(s). In carrying out such assessments, an aspect of vulnerability (degree of loss or reduction of ecosystem functions, resulting from potentially damaging events or pressures) is introduced, and ecosystem function vulnerability index is developed. There are many sets of environmental indicators or indexes developed by many organizations (e.g. SOPAC, 1999; World Economic Forum, 2000; Patkins *et al.*, 2000). Nakamura and Hutton (2002) developed a vulnerability index, focusing on flood impacts and damages, taking into consideration ecosystem functions (Table III).

Some of the ecosystem functions may often be emphasized by economic values, leading to destruction of integrity of the ecosystem and negligence of other ecosystem functions. In some cases, small ecosystems, such as riverine deltas, are not recognized as significant in terms of ecosystem functions and benefits associated with human life, and these small ecosystems normally are drained for development activities to achieve single economic benefits. However, detailed evaluation sometimes finds valuable ecosystem

Table I. Freshwater ecosystem functions: examples from wetlands in Asia and the Pacific (modified from UNEP/Wetlands International (1997); all the examples can be found in UNEP/Wetlands International (1997)

Ecosystem function	Examples from Asia and the Pacific
Flood control (floodwater storage, flood peak reduction, flood desynchronization)	Agusan Marsh, Philippines
Water supply	Tamiraparani River floodplain, Tamil Nadu, India
direct abstraction	Ganges floodplain, India and Bangladesh
maintenance of river flow	Marshes of Khao Sam Roi National Park, Thailand
ground recharge	
prevention of saline water intrusion	
Water quality maintenance and	Chaohu Lake, Anhui Province, China
purification	Artificial wetlands, Baiyan coal mine, Sichuan, China
removal of agricultural pollutants	East Calcutta Wetlands, India
treatment of mine drainage	
domestic and industrial waste water treatment	
Coastal storm protection and erosion prevention	Mangroves adjacent to Brisbane, Australia
Reduction of net greenhouse gases (GHGs) emission or absorptive capacity (sinks of GHGs)	–
Transport	Ogan-Komering *lebaks,* south Sumatra
Recreation and eco-tourism	Olango Island, Philippines
Forest resources (timber, fuelwood, tannin, etc.)	Sundarbans, India and Bangladesh
Wildlife resources (meat, furs, skins, etc.)	Mangroves of Malaysia, India and Bangladesh
Fisheries	Danau Sentarum complex, Kapuas River, Kalimantan, Indonesia
Plant resources (food, medicine, fodder, etc.)	Mangroves of Southeast Asia
Agricultural resources	Freshwater *beels* and *hoars* of Bangladesh
Maintenance of biodiversity	Sundarbans, India and Bangladesh
Cultural and heritage significance	Lake Lanao, Philippines

Table II. Classified services provided by freshwater ecosystems (drawn from IUCN (2000))

Category	Services
Production	• Water (drinking, irrigation, etc.) • Food (fishes, rice, etc.) • Raw materials (reed timber, etc.) • Energy (hydroelectric) • Species habitat • Generic information.
Regulation	• Buffering (storm protection, flood control, storage) • Biochemical cycling (carbon storage, methane) • Waste removal (filter-feeding invertebrates, sediment, micro-organisms, etc.) • Local climate
Other	• Recreation and tourism • Cultural uses • Transport

functions that can provide benefits for communities, particularly rural communities. The scale issue of ecosystem functions is again emphasized in terms of incorporating them into policy schemes of varying scales.

In meeting management objectives, there may be a danger of decreasing or losing some ecosystem functions. For instance, development of wetland forests for agricultural purposes is likely to result in the loss of many

Table III. Vulnerability indicators for flood impacts and damages (modified from Nakamura and Hutton (2002) excluding housing indicators) targeting 100 km^2 size

Land use
Land surface area (km^2)
Population
Agriculture
When flooding occurs (1 = immediately prior or during harvesting period; 0 otherwise)
Duration (0 = less than 5 days; 1 = 15 days; 2 = 6 weeks or more during growing seasons)
Crop type (0–2, depending on crop type significance in the basin)
Arable land area/land surface (%)
Depth (<2 m = 0; >2 m = 1)—loss of draft animals and livestock
Risk to life (for flashy catchments)
Steepness of slope
Ratio of discharge of 200 year return period flood to annual average flood
Slope stability under 200 year return period rainfall intensity
Economy
Economic value of flood losses as equivalent to a percentage of the Gross National Product OR as a percentage of Government income
Percentage of capital value of the basin's buildings, infrastructure and plant (if statistics available)
Critical industrial sites at risk (percentage production in specific categories, e.g. power)
Percentage basin's stable food production that might be lost in a flood (measured as proportion of average daily intake)
Population at risk as a proportion of the basin's population
Population
Newly urbanized areas populated by migrants from rural areas
Landless workers in rural areas
Elderly/disabled
Poor
Ethnic minorities
Female-headed households (both permanent and temporary, i.e. partner is a migrant worker)
Ecosystem
Ecosystems linked to river (0)
Ecosystems dependent upon artificially created water regime (1)
Number of internationally important protected areas
Nationally important protected areas
Locally important protected areas.
Number of endangered/rare/indigenous species (according to IUCN and national Red Books)
Natural and regrowth vegetation coverage
Percentage of degraded land
Degree of slope (average)
Use of chemical fertilizers (N, P and K) per unit area
Soil erosion rate
Recovery time >25 years (4)
Recovery time <25 years (1)

of the ecosystem functions relevant to wetland forests. In most cases, those who can benefit from such agricultural development are different from those who obtain benefits from the lost ecosystem functions. The World Commission on Dams final report (WCD, 2000) is taking a human rights approach to such social issues. The traditional Environmental Impact Assessment, or Cost Benefit Analysis did not fully take into consideration the full range of benefits that can be provided by the ecosystems. In the decision-making process, if a decision results in the loss of some ecosystem functions, some type of compensation measure (both from a socio-economic perspective and from an ecosystem perspective) should be taken and incorporated into the management objectives and schemes.

POLICY-LEVEL IMPACTS AND IMPLICATIONS OF THE ECOSYSTEM-BASED RIVER BASIN MANAGEMENT

The introduction of the ecosystem approach to river basin management has implications for necessary changes in the decisions and policies of river basin authorities.

First of all, the approach requires the introduction of the ecosystem concept into the planning and management of various sectors in decision-making tiers. For example, ecosystem functions of the agroecosystem, such as the water retention capacity of rice paddies, can be considered within the river basin framework (e.g., how much of the total run-off water should be retained in rice paddies?). However, the total rice paddy areas are actually likely to be determined by crop yields necessary to sustain the population or for export, and in this paddy planning, the function of water retention may not be taken into consideration. Therefore, the introduction of ecosystem-based river basin management will require all relevant sectors to consider all related ecosystem functions into their own sectoral planning.

Inter-sectoral coordination for river basin purposes was not successful because the management objective was always placed on water resources management. Moreover, the user-sectors of river basins placed priorities on their own resource uses without taking into consideration other relevant ecosystem functions. However, by introducing multi-resource and multi-objective river basin management, policy coordination among sectors may be facilitated.

A need for inter-sectoral coordination through the ecosystem approach eventually promotes a need for an 'ecosystem-based land use'. This means that land-use planning should be conducted based on the ecosystem functions to be utilized and enhanced by various land uses. By carefully analysing trade-offs among various ecosystem functions and selecting achievable river basin objectives, land use can be largely based on ecosystem functions.

Lastly, it is pointed out that the ecosystem approach may remobilize or redirect the financing for river basins. In the environmental fields and development sectors, there is independent and individual financing for addressing sector-specific issues and issue-specific problems. In river basin management, water-related funding could be provided. At the same time, if the Ecosystem-based River Basin Management proves to be an efficient and effective policy vehicle for addressing biodiversity conservation or addressing adaptation to climate change, then the funding for biodiversity and climate change, be it national or international, can or may be channelled through the Ecosystem-based River Basin Management. By eliminating duplicative efforts and coordinating funding through the ecosystem approach, more efficient and cost-effective management could be achieved.

ECOSYSTEM-BASED APPROACH IN THE YANGTZE RIVER BASIN IN THE PEOPLE'S REPUBLIC OF CHINA: A CASE STUDY

The government of the People's Republic of China has introduced an ecosystem approach to river basin management, after it recognized that the large-magnitude floods in the Yangtze River basin in 1998 and 1999 and floods in the Songhua River system in 1998 were associated with the degradation of ecosystem functions in the respective basins. UNEP assisted the government in setting up the policy in support of the development of preparations for future potential floods through conservation of ecosystem functions, and currently a project preparation is under way using the GEF Project Development Facility (PDF). The case of the policy development on ecosystem function conservation in the Yangtze River basin is introduced as an example of policy-level adoption of the ecosystem approach for river basin management with its goal of flood mitigation and control.

The Yangtze River is the largest river in China, with a watershed of approximately $1{\cdot}8 \times 10^6$ km^2. Within the Yangtze River basin, about 85% is plateaux, mountains and hilly areas, 11% plains and 4% rivers and lakes. There were many lakes in the mid and lower reaches, with the large ones being Dongting, Poyang, Tai and Hong Lakes, and the Jianghan Lake Group. The total water resources in the Yangtze River are estimated at

$961{\cdot}6 \times 10^9$ m^3, and the average annual discharge is 960×10^9 m^3. The Yangtze River Basin has a population of 411 million, and the population density amounts to 220 persons/km^2.

A number of plants and animals that can be found in the upper and middle reaches of the Yangtze River are endangered species listed as national priority protected species. The most notable ones include: dove tree (*Davidia involucrata*), single-leafed grass (*Kingdonia uniflora*), Minjiang cypress (*Cupressus chengiana*), giant panda (*Ailuropoda melanoleuca*), golden monkey (*Rhinopithecus* spp.), and lesser panda (*Ailurus fulgens*). The river and its associated wetlands are the habitats for fauna such as the Yangtze River dolphin (*Lipotes vexillifer)*, Yangtze alligator (*Alligator sinensis*), and David Deer (*Elephaurus davidianus*). Migratory bird species, whose seasonal habitats lie in wetlands within the Yangtze basin, include the white crane (*Grus leucogeramus*) and the white-naped cranes (*Grus vipis*). It is estimated that the Yangtze River basin has great potential to sequester greenhouse gases in vegetation and soil through the sound management of forests and grasslands. Further, reforestation and soil conservation in the basin would reduce vulnerability to extreme hydrological events possibly associated with climate change.

The 1998 floods were caused by intensive and long rainfall, and were characterized by many peaks and quick peak arrival. The UNEP scoping mission carried out in January 1999 concluded that the following underlying factors and decreased ecosystem functions potentially contributed to the unusually close crests and the prolonged high water level period through quick run-off and reduced water retention capacity in rivers and associated wetlands (UNEP, 1999):

1. *Deforestation*: deforestation in the Yangtze River basin started in the 1950s. Today only about 10% of the basin is forested, although degraded forest areas are recovering after the logging bans introduced in the basin.
2. *Grassland degradation*: overgrazing is one of the major causes of grassland degradation in the headwater areas. Erosion associated with grassland degradation in the headwater areas amounts to 106 000 km^2 (27·4% of the total land area), of which 42 300 km^2 suffers from high degrees of erosion, and 1100 km^2 is categorized as having extremely high degrees of erosion.
3. *Soil erosion*: deforestation caused soil erosion in mountain areas of the Yangtze River basin, particularly on steep slopes (more than 25°). About 60% of cultivated lands on slopes have no soil conservation measures. In the 1950s, soil erosion areas were about 299 500 km^2, whereas today the degraded land areas amount to 393 000 km^2. As a result, sediment transport in the Jinsha River, for example, increased by more than 100% in 15 years (130×10^6 t year^{-1} in 1958, and 290×10^6 t year^{-1} in 1974) (UNEP, 1999).
4. *Loss of lakes and wetlands*: in the early 1950s, as many as 4033 lakes and wetlands existed in the Yangtze River basin. By 1995, approximately 1100 lakes had disappeared. In 1949, 22 relatively large lakes in the basin had a total of 17 198 km^2 of surface area. About two-thirds of this surface area was lost by 1980. This massive loss of lakes and wetlands, in particular in downstream areas of the Yangtze River basin, was a result of large-scale conversion to farmlands.

These environmental changes are associated with the local population, who have no other means but to exploit environmental resources in the basin to meet increasing demands for natural resources by the growing population.

Addressing these degraded environmental conditions in the basin, at the policy level, the government decided to formulate the Guiding Principles for flood control and damage mitigation, including logging bans, re-conversion of cleared land to forests, prohibition of cultivation on steep slopes, re-conversion of reclaimed agricultural lands to wetlands to recover the level of the 1950 surface water area, relocation of populations living in vulnerable areas, strengthening of river banks, and dredging of river channels. At the same time, the government introduced the 'Ecosystem Functions Conservation Areas' (EFCAs), outlined in the National Ecological Conservation Guidelines, drafted by the State Environmental Protection Administration (SEPA) and approved by the State Council at the end of November 2000. This new approach has inter-ministerial agreement, as all central ministries and agencies concerned were fully consulted in the legislation process. This new regulation aims to introduce EFCAs to maintain a sound ecological balance in areas essential for ensuring environmental safety, and those critical for alleviating and preventing natural disasters (SEPA/UNEP/GEF, 2002). More specifically, EFCAs are to be established in the areas where key ecosystem functions should be conserved to prevent natural disasters such as floods, particularly in important headwater areas, natural areas essential for flood control, important water conservation and soil erosion conservation areas, critical areas to prevent damage caused by hurricanes, and vulnerable coastal ecological regions. The Tenth Five-Year Plan covering the period of 2001–05, approved by the People's Congress of China in March 2001, includes the establishment of 10 national as well as 100 local EFCAs. The plan gives high priority to headwater areas and critical wetlands of the Yangtze River basin.

In the EFCAs, human activities negatively impacting key ecosystem functions, such as agriculture, animal husbandry and mining, can be restricted or regulated. However, the intention of the establishment of the EFCAs is not to prohibit economic activities totally, but to encourage and promote human activities to alleviate poverty of local populations that are also compatible with the ecosystem functions that have to be conserved. At the same time, the aims when designating the EFCAs are to achieve the river basin management goal (in this case, flood control), while achieving other global environmental benefits, such as biodiversity conservation, and minimizing land degradation and climate change.

The project through which UNEP will support the government of the People's Republic of China with GEF financing has the following objectives: (i) to develop methodologies to promote the sustainable use of natural resources in areas critical to global environment conservation and flood control, and (ii) to develop methodologies to promote the rehabilitation and conservation of ecosystem functions in degraded protected areas where the globally significant environment is at stake (SEPA/UNEP/GEF, 2002). At the same time, the project will strengthen the capacity of the central as well as local government bodies concerned to enable them to apply developed methodologies to the region as a whole in a flexible and sustainable manner. Emphasis will be placed on the sustainability of the project by fully taking into account the socio-economic needs of local populations. The project establishes such EFCAs from the perspective of flood control. However, by incorporating other ecosystem functions that are relevant to other aspects of water resources management, such as water quality maintenance into a river basin management scheme, this ecosystem function-based approach can address the integrity of the ecosystems of the river basin and the achievement of river basin objectives with maximum efficiency and without unnecessary conflicts among stakeholders.

The proposed project will consist of the following three major components:

1. *Assessment and planning for conservation of ecosystem functions*: the assessment will examine implications for the global environment, including flood-related ecosystem functions, as well as to enable the estimation of potential global benefits of the project. Ecological planning is to have ecosystem functions of the local natural environment integrated more appropriately into land-use plans. Concrete ecological planning will provide the ministries and local governments concerned with sound guidance on how existing land-use plans are to be modified to incorporate essential ecosystem goods and services and functions of the local natural environment.
2. *Ecological monitoring and early warning system*: early detection of critical environmental changes will enable the government authorities concerned to take necessary action in a flexible and timely manner. The proposed monitoring and early warning system will provide an effective and economic surveillance tool for strengthened management of ecologically critical areas. The system will focus on periodic monitoring of key local ecosystems to detect timely critical changes in ecosystem functions.
3. *Demonstration activities on EFCAs*: EFCAs will be set up and managed in a few locations in the upper and middle reaches of the Yangtze River. These demonstration activities are essential to confirm effectiveness and to identify drawbacks of the new approaches to be introduced in the basin. It is emphasized that the new approach seeks a sound balance between the conservation of key ecosystem functions and local economic activities.

As indicated above, the GEF PDF activities are under way, and the results of the EFCA approach at the policy level are yet to be produced by the anticipated project.

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