UNEP Collaborating Centre on Water and Environment

UCC-Water

Addressing Environmental Aspects and Ecosystem Issues in Integrated Water Resources Management

Merging IWRM and the Ecosystem Approach

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Addressing Environmental Aspects and Ecosystem Issues of IWRM

1. Introduction

Integrated Water Resources Management (IWRM) was established at the UN Earth Summit of 1992, when the water community was challenged by the Dublin Principles to address water management issues in a more holistic and sustainable way. The Earth Summit also established the Convention on Biological Diversity (CBD)[1], from which evolved a parallel and in many ways supplementary effort on developing the Ecosystem Approach (ESA), addressing management issues related to the CBD.

Initially, IWRM had its primary focus on *water and land*, and ESA had its focus on *living resources*. However, the two approaches are now being merged via the issue of *environmental sustainability in socio-economic development*[2]. Ecosystem –or environmental– sustainability in socio-economic development is achieved by balancing the costs to and the benefits from the ecosystems assets of waters and wetlands.

The purpose of this note is to assist planners and implementers of IWRM in starting to address the environmental and ecosystem aspects of IWRM. This need is noted the Global Water Partnership's definition of IWRM which describes the approach as, "a process which promotes the coordinated development and management of water, land and related resources, in order to maximise the resultant; 1) Economic and social welfare, in an; 2) Equitable manner without compromising; 3) the sustainability of vital ***Ecosystems***"[3].

The following section presents a brief introduction to ecosystems and the ecosystem approach (ESA). Central to the link between ecosystems and human well-being are the functions of an ecosystem which can be defined as, "the capacity of natural processes and components of natural or semi-natural systems to provide goods and services that satisfy human needs[4]". Particular attention is given to the significant, but often overlooked, goods and services provided by healthy wetland ecosystems (such as safe water, fisheries, wood and fibre products, waste purification, and flood retention); but also to the costs associated with damaging wetland assets by non-sustainable development practices.

Section 3 presents the fundamentals of the IWRM approach to manage water resources in an economically effective, socially equitable and environmentally sustainable way. This include the three pillars of sound water governance and the key issue of cross-sectoral integration.

Section 4 summarizes the well established environmental management issues related to water sector management. These include impacts like pollution, erosion, etc. caused by economic sector development. Also, the section discuss the issue of water for nature, and the efforts to protect and conserve valuable natural wetlands

In Section 5, focus on the crosscutting issue of environmental sustainability of *valuable ecosystems*. The assets of ecosystem goods and services is introduced to define these values and the issue of balancing costs and benefits to these assets is discussed.

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[1] Convention on Biological Diversity (2000) (http://www.cbd.int/convention/guide.shtml)

[2] The link between environmental sustainability and development is noted in Millennium Development Goal 7 (http://www.un.org/millenniumgoals/#)

[3] See: Global Water Partnership (2000); Integrated Water Resources management, GWP TEC Background Paper no 4 (www.gwpforum.org). These three elements are often referred to as the three "Es" of IWRM.

[4] See: www.ramsar.org/key_csd6_iucnwwf_bkgd.htm

Section 6 contains concluding remarks on the potential synergies between IWRM and ESA. While annex 1 contains recommendations for how to begin to implement environmental aspects of IWRM; Annex 2 contains an overview of environment and ecosystem aspects related to water sector developments.

It is important to emphasise, that this note is not to be considered as a straight-jacket for national and regional approaches. It is meant as food for thought within considerations of the specific national contexts. Modification – even rejection – is welcome, as long as it is based on a serious analysis of how environmental sustainability aspects may be best promoted in actual practices in the national and local development contexts.

2. Linking Ecosystems and People: The Ecosystem Approach

2.1 The Ecosystem Approach

The "ecosystem approach" (ESA) has – generally speaking - been developed and advocated by the biological science community and it pays strong attention to the complex interaction between the natural ecosystems and human activities It was formally proposed by the 5th Conference of Parties to the Convention on Biological Diversity in 2000. The approach is, "*a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way*"[5] (the similarity to the IWRM concept defined in section 1 is striking).

Accordingly, ESA basically focused on *conservation* of forests, grasslands, wetlands, coastal areas, etc, but with acknowledgement of the need for *use*

Its objective is to balance the three objectives of the biodiversity convention: These are: i) conservation; ii) sustainable use; and iii) equitable sharing of the benefits arising out of the utilisation of genetic resources[6]. In this context, proper water management is a key factor in achieving these objectives.

ESA requires adaptive management to deal with the complex and dynamic nature of ecosystems, often with incomplete knowledge or understanding of how they function. Ecosystem processes are often non-linear and the outcome of such processes often shows time-lags. The result is discontinuities, leading to surprise and uncertainty. Management must be adaptive in order to be able to respond to such uncertainties, and contain elements of learning-by-doing and research feedback[7].

There is a need for flexibility in policy-making and implementation. Long-term, inflexible management is likely to be inadequate or even counter-productive and destructive. Ecosystem management should be envisaged as a long-term process that builds on the results achieved as it progresses. This learning-by-doing also serves as an important source of information to enhance knowledge of how best to monitor the results of management and evaluate whether established goals are being attained. In this respect, it is desirable to establish or strengthen capacities for monitoring and evaluation.

Ecosystem managers must consider the effects (actual and potential) of their activities on adjacent ecosystems. Management interventions in specific ecosystems often have unknown or unpredictable effects on other ecosystems. Therefore, possible impacts need careful consideration and analysis. This may require new arrangements or new ways of organisation for institutions involved in decision-making to make appropriate compromises.

In order to maintain ecosystem services, the conservation of ecosystem structure and function is a priority target of ESA. Ecosystem function and resilience depend on a dynamic relationship within species, among species and between species and their abiotic environment, as well as the physical and chemical interactions within the environment. The conservation and, where appropriate, restoration of these interactions and processes are of greater

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[5] Convention on Biological Diversity (2000); (http://www.cbd.int/programmes/areas/forest/cs.aspx)
[6] Convention on Biological Diversity (2000); (http://www.cbd.int/convention/guide.shtml)
[7] For more information on adaptive management: http://www.adaptivemanagement.net/; http://www.doi.gov/initiatives/AdaptiveManagement/index.html

significance for the long-term maintenance of biological diversity than simply the protection of species.

2.2 Water Management and the Ecosystems Approach

In metaphorical terms, water, including its nutrients, can be considered as the bloodstream of ecosystems, while land and soils can be considered as the bones. This is a symbiotic relationship; whereby healthy ecosystems are essential for safe and sufficient water resources, and *vice versa*. Healthy ecosystems in river catchments turn rainfall into runoff and help establish and replenish groundwater aquifers that humans can exploit.

The river basin – including lakes, wetlands, groundwater aquifers and estuaries – forms the basic unit for applying ESA in IWRM. But where traditional river basin management focuses on *water*, ESA also includes *living organisms* and encompasses the essential structure, processes, functions and interactions among organisms and their environment. And equally importantly, this approach recognises that humans are integral components of most ecosystems.

Within a particular river basin, it is practical to identify a number of different but interdependent and linked ecosystems, as illustrated in figure 1 below. These sub-systems each have there own characteristics and also their particular management needs.

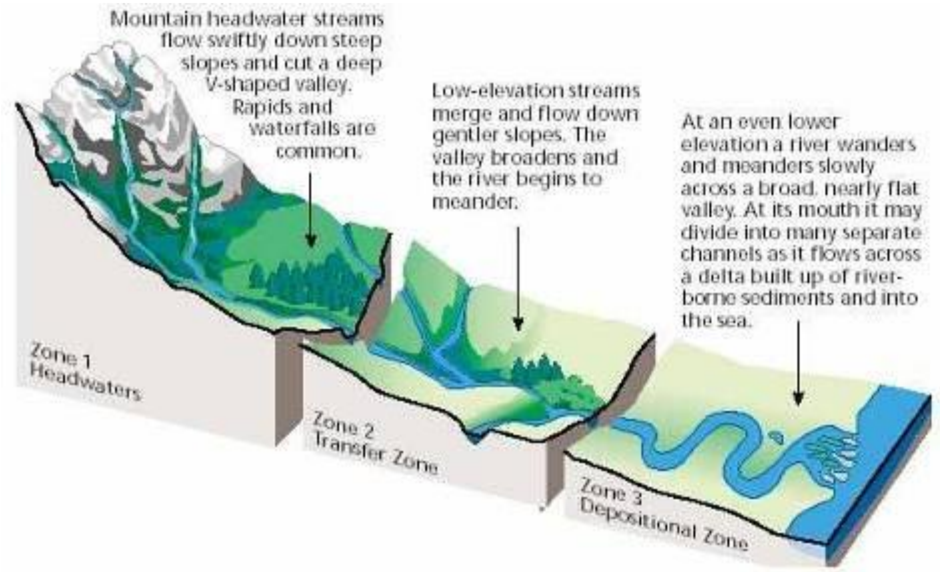


Figure 1: The river basin as an ecosystem of inter-linked habitats[8]
(Source: Federal Interagency Stream Corridor Restoration Working Group)

<u>Soil ecosystems: The link between rain and runoff.</u>

By a first glance, Figure 1 shows the traditional perception of the three basin ecosystems. However, there there is an additional, almost invisible black line in the figure, which deserves just as much attention as the other three: The ecosystem of the soils.

[8] Source: Federal Interagency Stream Restoration Working Group, 1998

The upper soils are not only the rain water harvester and flow mechanism for both groundwater recharge and overland flows to the creeks and rivers. They are also a living ecosystems by themselves, where communities of rodents, worms, bacteria, etc. process plant detritus on the surface into nutrients and water storage capacity.

The soils are efficient chemical reactors, where nutrient are produced for crops and vegetation, but also lost as contaminants of groundwater and surface water. Also, the are processors of toxics, such as pesticides. Some pesticides may be neutralized by soil processes, others may not. The microflora may also be able to process chemical spills such as oils and other organic wastes.

With respect to poverty and hunger alleviation it should be noted that about 80% of agricultural soils are rainfed (or rain water harvested). In this context, the proper management of soil water deserves just as much attention as management of irrigation water. Also the health and productivity of natural ecosystems like forests and grasslands are based on the soil.

Accordingly, the hydraulic, chemical and biological processes in soils deserve a prominent consideration in comprehensive ESA, involving the approaches of soil science.

Catchment ecosystems: Providers of water - and timber.

For centuries, the river basin headwaters where located in sparsely populated regions, with a predominance of natural and undisturbed ecosystems such as forests, grasslands, mountain meadows, etc. The catchments "caught" the rain and provided high-quality water supply for downstream users, probably one of the most appreciated ecosystem services.

Before the population explosion, the human impact was limited to low-intensity (and generally sustainable) practicing of shifting agriculture or lifestock herding, in balance with the productivity of the ecosystems. However, growing populations – combined with the economic value of timber – put heavy pressures on these ecosystems, as evidenced everywhere outside strictly protected areas. Flora, fauna – and soils – have been depleted by unsustainable ecosystem exploitation. And management practices have not been able to catch up.

These issues are traditionally and with good reason handled by foresters and agronomists. But to water managers, the headwaters are the "producers of ample and safe water supplies". And precondition for safe and clean water is the maintenance of healthy vegetation cover to prevent erosion and sedimentation. And also – even though this is still being debated[9] – as an important factor in flood alleviation and dry season augmentation. Therefore, there is a need to involve all three groups in a comprehensive water management..

Floodplain ecosystems: Providers of food, fish – and pollution.

[9] See: FAO and CIFOR (2005): Forests and floods: Drowning in fiction or thriving on facts.

The flood plains comprise the rivers, lakes and wetlands, as well as the surrounding lands. They were – long before the invention of water management – the crucibles of civilization and progress. Food and fibre - the key ecosystem goods and services based on fertile soils and ample water supply - have always served as a fundamental catalyst for economic development. And also as an example of what can happen when these assets are mismanaged. This is where our society and our management practices emerged, and they are still a core asset to this day.

Floodplain ecosystems host the most productive croplands, the most important inland fisheries and – at the moment – the most people, particular among the poor. They may also serve as important flood and drought alleviation “infrastructure”. This is where intensive and irrigated agriculture is most feasible, but also where one finds the emerging urban populations with their hot-spot issues in the form of water supply needs and pollution discharges.

For water managers, this is their traditional key area, dealing with needs for irrigation diversions, water supplies and waste discharges, as well as flood protection. But from an ecosystem point of view, these areas are also catchments, and non-irrigated agriculture plays a significant role in the *soil water* management.

<u>Coastal ecosystems of estuaries and coasts</u>: Providers of fish – and recreation.

The coastal areas host some of the worlds most diverse and productive ecosystems. Estuaries, lagoons, mangroves and coral reefs have for millennia provided stable supplies of food and fiber. They have their share of flood problems from storm surges and tsunamis, but rarely face the devastating drought miseries in the flood plains. Also, they have the economic advantage of easy access to trade with other regions, and therefore, they became the host the undisputed economic centres of todays global economy. And finally, they became very important assets in the global tourist sector.

But at the same time, they became the victim of the “tragedy of the commons” where free and easy access to shared assets led to the same severe degradation as was seen in the catchment forest. Resources with out established ownership are “priceless” to the users, and therefore easy victims in modern economies

However, coastal issues are of limited concern to traditional water management, as salty or brackish waters are useless for water supply for people and crops . Actually, their upstream actions often have compounded the coastal problems, when stream flow depletion changes the sensitive ecological balances in the estuaries. And when pollution and sedimentation destroy the life as well as the rearing grounds of the coastal zones.

In summary, the traditional upstream water manager does not need to be concerned about the downstream impacts in the coastal zoen. But in an ecosystem approach, she should be. ESA implies inter-disciplinary approaches by hydrologists, limnologists, marine and terrestrial biologists, as well as soil scientists. **L**inking water and ecosystems via ESA implies a consolidation of the present silo-like, sector approach in the management efforts of foresters, soil managers, water engineers and marine biologists. Only in this way can the management of a system where the various sector uses (such water for people, water for food, and water for nature) become integrated in true accordance with the IWRM approach.

3. Linking Water Resources and People: The IWRM Approach.

Integrated Water Resources Management (IWRM) has – roughly speaking - been developed and advocated by the water engineering community and pay strong attention to the complex interaction between the quantity and quality of the water resources in relation to the various sector uses. It was initially proposed by the Rio Earth Summit in 1992 and now constitutes an internationally acknowledged framework for water governance. It is defined as, *"a process which promotes the coordinated development and management of water, land and related resources, in order to maximise the resultant economic and social welfare, in an equitable manner without compromising the sustainability of vital ecosystems"*[10].

Generally speaking, IWRM is basically focused on *use* for people, food, nature and other purposes, but with acknowledgement of the need for *conservation* of vital ecosystems.

3.1 General Framework

The general framework of the IWRM approach to water management is illustrated in figure 2.

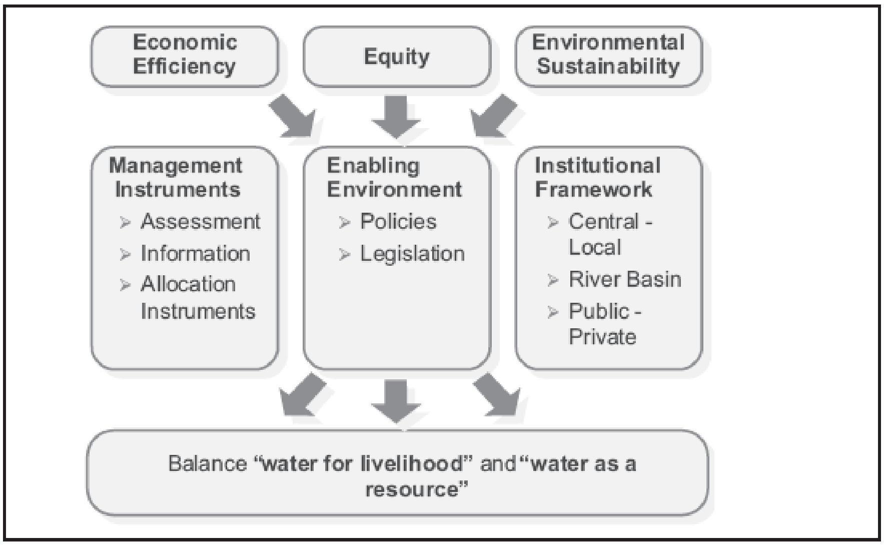


Figure 2: The general framework of IWRM

To implement the IWRM objectives, there is a need to ensure coherence and appropriate linkages between the main national and local ***development objectives*** with respect to:

- *Economic development objectives* relating to monetary resources, such as economic growth, management of monetary assets, and economic sector development.
- *Social development objectives* relating to human resources, such as poverty alleviation, health, education, and job creation.
- *Environmental development objectives* relating to natural resources, such as water policies, pollution control policies, nature conservation policies, agricultural land policies, forest policies, and fisheries policies.

The above objectives have to be achieved through a comprehensive development of; 1) the enabling environment in the form of policies, strategies, legislation, etc.; 2) The institutional

[10] Global Water Partnership (2000): Integrated Water Resources management, GWP TEC Background Paper no. 4 (www.gwpforum.org)

roles of the various stakeholders in the water sector; 3) The management instruments such as planning tools, monitoring, regulation and economic incentives.

3.2 Cross-sectoral Integration

IWRM places emphasis on achievement of cross-sectoral integration via coordination and collaboration, as illustrated by the "IWRM Comb" in figure 3 below.

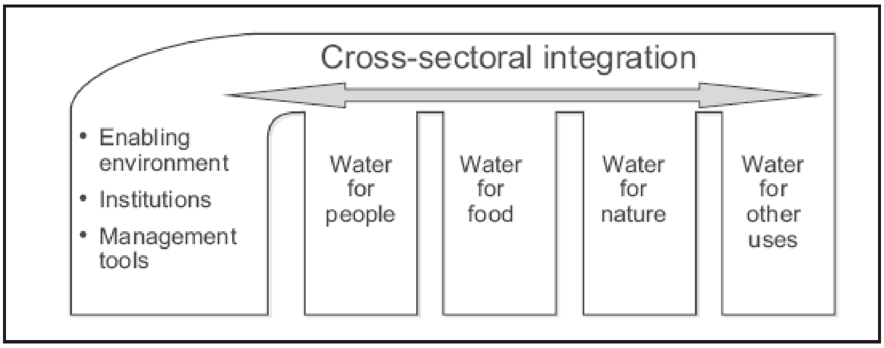


Figure 3: The IWRM Comb: IWRM and its relation to sub-sectors

The IWRM approach strives to ensure coordination of *all* sector uses, so that the impacts of one particular user are taken into account for all other affected users. Consequently, planners for water supply and sanitation (Water for People), for irrigation and fisheries (Water for Food) and for nature conservation (Water for Nature), and so on, must take other needs into consideration, particularly in terms of water allocations and impacts.

However, much less attention has been given to introducing practical approaches to the more fundamental issue of the environmental sustainability within IWRM. Recently, this issue has been considered intensively by the Millennium Ecosystem Assessment[11], which concludes that, a "water resources goods and services approach" is one where the development assets of the aquatic ecosystems are the focus as engines for poverty alleviation and economic growth. This approach directly links environmental sustainability aspects to other national, sub-regional and local economic and social development aspects.

Depending on the particular political and administrative context, any sub-sector approaches and ESA may be applied – separately or combined – to incorporate environmental aspects into the implementation of IWRM. For example, where water pollution is a priority issue and enforcement is weak, it may be most appropriate to apply the water pollution approach. If the country has important and valuable wetlands that provide, among other things, food and fibre for the poorest (and often large tourism development potentials), it may be appropriate to emphasise water and nature. Or if the national environmental authorities are well developed, it may be possible to start considering environmental goods and services as an important development asset – particularly in efforts to mainstream environmental issues into economic and social development policies. To do so does not automatically imply detailed research and awkward top-down approaches. It may be gradually introduced through a process of dialogue and consensus making among key stakeholders. By doing so, environmental issues can be considered as important development asset, and not, as it is often perceived, as a development burden and constraint.

[11] Millennium Ecosystem Assessment Board (2005): Living beyond our means (see http://www.millenniumassessment.org)

4. Achieving Cross-sector Coherence of Environmental Water Management

One objective of strengthening the environmental aspects in IWRM is to achieve coherent consideration of environmental water aspects into water sector management

For many good and historical reasons, the concept of water and environment has been developing around two - partially separated – issues: (i) Water *pollution* and (ii) wetland *conservation.* This section will discuss these two perceptions.

4.1 Water for People, Food and other uses: Pollution

The environmental aspects of “Water for People” have been extensively addressed through national and international efforts to reduce water pollution. Management of wastewater discharges from urban and industrial development has been implemented through a multitude of policies, laws and regulations, as well as through innovative use of demand management (also related to public health impacts and wetland degradation). This is one of the oldest and most developed approaches in environmental management of water resources, directed towards maintaining an acceptable water quality of a nation’s water resources. An increasing number of management interventions have been directed towards the “Water for Food” issue, by addressing pollution from nutrients and pesticides from non-point sources in agriculture.

Back in the late 1960s and early 1970s when many Environmental Protection Agencies (EPAs) were founded, the issue of water and environment was primarily related to the issue of water pollution. The populations, and subsequently the politicians, in the North found that the pollution impacts of untreated wastewater releases into the rivers and oceans were not acceptable, as they threatened both safe water supply and recreational needs. Accordingly, an initial priority for environmental agencies was, and still is, the restoration and protection of the quantity and quality of a nation’s waters resources.

Addressing the issue of water pollution is a key factor in achieving the MDGs related to health.

The key indicator in the management of water and waste is the chemical and bacteriological composition of water. These characteristics have significant impacts on public health as well as on the health and productivity of the waters. Initially, much attention was paid to reducing the effects of human wastewater on the oxygen conditions (biological oxygen demand and dissolved oxygen conditions) in rivers and lakes through primary and secondary treatment.

Later, the need to address the nutrient emissions of nitrate and phosphorus to fight eutrophication was included in more costly tertiary treatment efforts.

Also in the 1960s and 1970s specific scandals and accidents (like the Love Canal episode in the USA and the pollution of the Rhine) showed the need to protect the water resources (including groundwater) from releases of toxic chemicals, from leaching from waste dumps, and from industrial wastewater discharges; not least because modern production methods have introduced new and potent chemicals. Even the most advanced precautions do not guarantee safety against the likes of accidental spills and operational deficiencies.

Toxic spills – as well as oxygen depletion due to eutrophication – may have fatal impacts on fisheries and the welfare of the poor.

Later, the impact of agricultural practices and of general land use came into focus. In many cases, leaching of surplus fertilisers has significant impacts on water quality and threatens groundwater aquifers as well as the biological stability of lakes and coastal waters. Inappropriate use of pesticides has also been shown to cause serious problems in maintaining the quality of both groundwater and surface water.

Additionally, land use changes may result in significant water pollution. Logging and deforestation for land reclamation increase sediment loads of rivers and add to their nutrient loads. Irrigation systems – not least the high intensity approaches with large fertiliser and pesticide demand – change the soil – water dynamics (in particular the salinity conditions) and impact groundwater recharge and river flows.

Accordingly, attention to the quality of the waters in a basin – affected by the users of both water and land in the basin – is a key theme in addressing environmental aspects in IWRM. This issue is also directly related to the Millennium Development Goal 7, on the environment, and the specific targets 9 and 10 on sustainable development and water and sanitation[12].

[12] http://www.mdgmonitor.org/goal7.cfm

4.2 Water for Nature: Wetland Conservation

"Water for Nature" puts emphasis on protection and restoration of the biodiversity of aquatic ecosystems. This approach is closely related to the concept of Environmental Impact Assessment (EIA) and of minimizing environmental impacts.

In the 1970s, environmental perception was gradually expanding to also include conservation of nature. Conservation, in particular through protected areas, is a concept born long before the environmental movement, but the appeal of and public attention to the cause of environmental "protection" attracted the international conservationists of the time, such as NGOs like the IUCN[13] (International Union of Nature *Conservation*) and WWF[14] (initially called World *Wildlife* Fund).

Many of these stakeholders were biologists and foresters in the national parks. They represented an important new branch of the environmental aspects of water resources that began to emerge, namely "wetland conservation". This is most clearly expressed in the establishment of the Ramsar (1971)[15] and Bonn (1979)[16] Conventions.

This school of environmentalists established, through the Convention on Biological Diversity (1992), the concept of the "ecosystem approach" which is an important complement to the IWRM approach with respect to environmental sustainability issues.

Basically, the "Water for Nature" perception addresses the protection and/or rehabilitation of the biological health and productivity of aquatic ecosystems within a basin, such as in upland catchments, floodplains, lakes, swamps, and estuaries. The ecosystem approach implies also that coastal waters are included in deliberations. A key indicator of proper consideration of water and nature issues is a healthy and diverse fish population.

The important Ramsar site of Chilika Lake in Orissa, India, was rapidly deteriorating due to salinity changes and sedimentation. A concerted effort by the Chilika Lake Authority has drastically improved the health of the lake for the benefit of local fishermen and farmers

An important approach to addressing the water and nature issue is the so-called "environmental flows" approach i.e. the water flow (including the appropriate variability regime) and water quality needed to ensure an ecosystem's health in accordance with the set

[13] See http://www.iucn.org/
[14] See http://www.wwf.org/
[15] See http://www.ramsar.org/
[16] See http://www.cms.int/

of socio-political targets for the systems. Addressing the environmental flow issue is an important component in state-of-the-art management of aquatic ecosystems[17].

However, within the wider concept of ESA, it is necessary to consider more than just water quantity and quality. Land issues like the characteristics of the upland catchments and floodplain morphology (including river beds and artificial levees and weirs) are also important parameters in the "Water for Nature" approach of IWRM.

[17] Dyson M. *et al* (2003): Flow: The essentials of environmental flows. See www.waterandnature.org

5. Sustainability of Vital Ecosystems: Managing Wetland Assets

Experience shows (as documented above and by cases in the GWP ToolBox[18]), that environmental sector aspects may be well addressed through the IWRM approach. However, there is less guidance available when it comes to achieving the third "E" in IWRM: The *sustainability* of vital ecosystems.

This is unfortunate, particularly as the environmental sector aspects often appear to politicians and development planners as a burden to economic sector development (and therefore not affordable to developing countries). However, central to the link between ecosystems and human well-being is the concept of ecosystem functions which are defined as *"the capacity of natural processes and components of natural or semi-natural systems to provide goods and services that satisfy human needs"*. Consequently, ecosystem functions should be considered as "natural infrastructure" or "natural resources assets", with huge importance for socio-economic development and stability.

Some directions can be found by considering the two other "Es": Economic efficiency is quite clear, it means maximising the economic benefit/cost ratio in water development projects and programmes. Social equity cannot in the same way be put in economic terms, but it implies striking a "fair" social balance between the different user needs.

Similarly, it may be proposed to consider ecosystem sustainability as striking a – not necessarily economic – balance between the benefits and the costs of degrading aquatic ecosystems, which are very frequently of vital importance to the poor in rural areas, but also of significant importance for more affluent urban populations. An ecosystem's resources should be seen as *assets and not as burdens* to national development, as similar to financial resources and human resources.

The issue of ecosystem assets was taken up in The Economist on 23 April, 2005. Here the front page picture (left).

Ecosystem sustainability also implies that IWRM should look beyond the freshwater of the rivers, lakes and groundwater. It should also account for the rain water infiltrating into the soils providing the basis for plant and crop growth, as well as for brackish and saline waters near coasts.

[18] IWRM ToolBox, Global Water partnership see: http://www.gwptoolbox.org/

It is immediately apparent that in doing so, IWRM and ESA become complementary approaches with a high potential for exploiting each other's synergies. IWRM may benefit from ESA's emphasis on ecosystem functions and their relation to the water resources. And ESA may benefit from IWRM's emphasis on governance[19].

Consequently, by combining the objectives of both IWRM and the ESA, the environmental sustainability objective of the third "E" in IWRM may be expressed as:

"Achieving an optimal balance between the benefits and the costs of human impacts on the ecological assets (goods and services) of a region's waters"

One may, at least conceptually, speak of maximising the "environmental benefit/cost ratio", similar to the traditional economic benefit/cost ratio. This benefit/cost coefficient may not (and often cannot) necessarily be expressed in quantitative economic terms. However, it may be used as the basic framework for socio-political stakeholder discussions and consensus making in addressing conflicts in a basin, a region or a nation.

As discussed below, the benefits will primarily materialize within the river basin. However, the costs may be caused by both internal and external causes. Chapter 5 concludes with suggesting possible approaches for balancing costs and benefits.

5.1 The Environmental Benefits: Ecosystem Assets

The environmental benefits – or assets – are defined for each specific case in the form of goods (such as potable water, irrigation water, crops, fibers and fish) and services (such as wastewater processing , flood regulation and recreation).

These assets depend on the characteristics of the ecosystem, whether it is an upstream catchment, a floodplain or a river delta. Some assets are directly related to aquatic ecosystems (such as to water supply and to fish), whereas others are indirect input to terrestrial ecosystems (such as soil moisture and land erosion) The Millennium Ecosystem Assessment provides an overview of the multitude of goods and services provided by a healthy ecosystem, as shown in figure 4 .

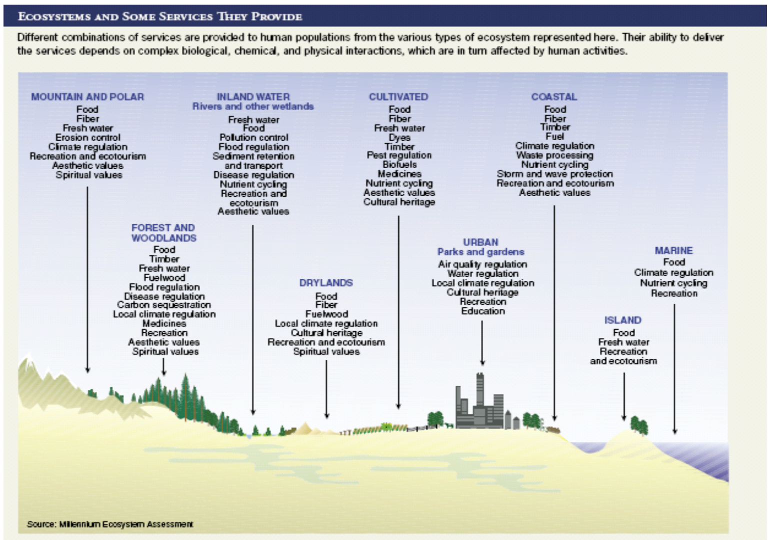


Figure 4: The ecosystem goods and services[20]

[19] As noted in section 3.1, IWRM focuses on governance in relation to; 1) the enabling environment in the form of policies, strategies, legislation, etc.; 2) The institutional roles of the various stakeholders in the water sector; 3) The management instruments such as planning tools, monitoring, regulation and economic incentives.

[20] Millennium Ecosystem Assessment (2005): Living beyond our means. Natural assets and human wellbeing. See http://www.millenniumassessment.org/en/index.aspx

If we link this thinking back to the four ecosystem components described in section 2.2, we find the following:

The soil ecosystems are the rainwater harvesters where rain and plant detritus are processed into

- water storage
- surfacewater flow,
- groundwater recharge and
- nutrients and enzymes for plant growth

The upland ecosystems of the headwaters are "producers" of water (and sediment):

- Glaciers: Provide stable and clean water sources
- Forests: Provide clean water, flood and sediment regulation, food, fuel and timber, free assets for poverty alleviation
- Rivers and lakes: Provide flood regulation, food and fibre for upland people, recreation

The floodplain ecosystems are providers of food and fibre:

- Fertile and wet soils: Provide high natural productivity, resources for poverty alleviation
- Lowland forests: Provide clean water, food, fuel and timber,
- Rivers, lakes and wetlands: Provide flood regulation, food and fibre, waste processing, recreation

The coastal ecosystems in the estuaries and along the coasts are providers of food, trade and economic opportunity:

- Fertile (and flood prone) soils: Provide high natural productivity
- Mangroves and lagoons: Provide food, fuel and fibre, income
- Coastal waters: Provide recreation, food, income

In many cases, a lack of reliable data prevents detailed economic assessments. Nevertheless, it is often possible – in a specific social and political context – to consider the value of these goods and services through transparent and fair multi-stakeholder dialogues and conflict mediation efforts. But this should not be an excuse to avoid serious and continued efforts to attach monetary values to ecosystems[21].

Some goods and services can be more easily evaluated, such as;

- Water supply in relation to urban, industrial and agricultural development
- Hydropower
- Waste processing in relation to public health
- Fisheries resources in relation to food security and job creation
- Flood retention properties of natural river plains
- Tourism potential of lakes, wetlands and coastal areas.

Many – if not most – of these ecosystem assets may become income generating mechanisms if appropriate markets can be established

[21] Emerton, L. and Bos, E. (2004): Value. Counting ecosystems as water infrastructure. See: www.waterandnature.org

The "free ecosystem profits" of rivers and wetlands in the Lower Mekong (right) have been estimated to 0.8 billion USD/year. They are directly comparable to "irrigation system profits" of 1 billion USD/year [22].

5.2 Direct Environmental Costs of Economic Sector Development

As demonstrated above, the ecosystems in a river basin (such as rivers, lakes, wetlands, aquifers, estuaries, catchments and floodplains) provide many – often overlooked – benefits to support economic development. Unfortunately, economic development often causes detrimental impacts on the environment such that socio-economic costs are borne by population groups who do not benefit from the economic development activities.

Many nations have established procedures for environmental impact assessments (EIAs) of development projects. However, a focus on specific infrastructure projects often leads to the neglect of equally important impacts of economic development policies, land development policies, migration policies, urban and industrial development policies, etc. Therefore, the intention of the ecosystem approach is to expand the EIA procedures to also address such general issues, as propsed in the Strategic Environmental Assessment approach.(SEA)[23]

Severe flooding in Jakarta (right) in 2007 caused heavy economic and social costs. The situation was made worse by urban encroachment on natural retention wetlands in the area. Also, deforestation in the hinterland was blamed for the severity of the situation.

[22] Ringler C. (2000): Optimal allocation and use of water resources in the Mekong River Basin: multi-country and intersectoral analyses. PhD dissertation, Rheinischen Friedrich-Wilhelms Universität, Bonn, Germany

[23] See e.g. http://en.wikipedia.org/wiki/Strategic_Environmental_Assessment

Examples of costs on river basins resulting from sector developments include:

- Upland catchment ecosystems:
    - Changes to environmental flows by dams established for hydropower generation, flood mitigation and water storage
    - High sediment and nutrient yields from depleted forests caused by logging and agricultural encroachment
    - Fertiliser and pesticide pollution from intensive upland and highland agriculture developments, such as orchards and vegetables
- Floodplains:
    - Regulation of lakes by weirs and dams
    - Hazards to life, hosing and infrastructure due flooding.
    - Over fishing and use of inappropriate fishing methods
    - Impact on environmental flows caused by dams and reservoirs built for hydropower generation, flood mitigation and water storage
    - Dredging and canalization of river beds for improvement of navigation
    - Constriction of river flows by levees for flood protection
    - Drainage of wetlands for agricultural development
    - Depleted flood-plain forests
    - Water intakes and fertilizer and pesticide pollution from intensively cultivated, irrigated and flood prone agricultural lands
    - Water intakes by and organic and bacteriological pollution loads from towns
    - Water intakes by and pollution loads from industries, in particular toxic chemical wastes and spills
    - Heated water emissions from thermal and nuclear power plants
- Estuaries:
    - Over fishing and use of inappropriate fishing methods
    - Changes in salinity caused by coastal protection infrastructure and saltwater barriers
    - Changes in salinity due to upstream regulations and water intakes
    - Depleted mangroves caused by logging and land conversion
    - Fertilizer and pesticide pollution from intensively cultivated and flood prone agriculture
    - Pollution from aquaculture practices
    - Water intakes by and organic and bacteriological pollution loads from towns
    - Water intakes by and pollution loads from industries, in particular toxic chemical wastes and spills

As in the case of benefits, the monetary value of such costs can be difficult (although not impossible) to establish. As already noted, through political dialogue and conflict mediation a more equitable balance between the benefits and the costs can be achieved. It should also be noted that public health costs and water supply treatment costs add to the direct ecosystem costs when ecosystems are damaged. These costs are often more readily estimated and may well be found to be of significant magnitude, even in comparison with the gross domestic product (GDP) of a nation[24].

[24] CNN (2005): "It's estimated that between 8 and 10 percent of China's GDP is off-set by environmental damage," says Professor Gerald Fryxell, a specialist in environmental management at the China Europe International Business School in Shanghai. Other estimates go even further, arguing that much of the growth China's economy has seen over the past quarter century has effectively been cancelled out by the heavy cost to the environment and by uncontrolled waste of resources.
See http://edition.cnn.com/2005/WORLD/asiapcf/04/27/eyeonchina.environment/

Irrigation development for cotton production in the catchments to the Aral Sea has had severe impacts on the fisheries in the lake and the socio-economic conditions in the region (right).

5.3 Indirect Ecosystem Costs of Climate Change

Climate – solar radiation with its associated temperature and precipitation – is the primary energy source of all ecosystems. Therefore, changes to this fundamental driver may potentially cause significant and often unexpected changes in ecosystem functions. Fossils and sediments testify to this basic global condition. Indeed, human history in the millennia after the last ice age has repeatedly demonstrated how ecosystems like the Sahara have critically changed the conditions for human settlements. Fortunately, humans have largely been able to cope with these changes through adaptation or migration, when exploitation of the natural resources has threatened their productivity.

Over the last 30-40 years it has become increasingly apparent that the present mode of economic development may potentially bring about significant impacts on the climate as a direct result of the "green house effect"; caused by burning of fossil fuels and other human activities. Until several years ago, there has been significant scientific and political disagreement about the importance of these effects and their impacts; but in more recent times the Intergovernmental Panel on Climate Change (IPCC) has published two important summaries for policy makers detailing their concerns[25].

These summaries conclude that changes in the atmospheric abundance of greenhouse gases and aerosols alter the energy balance of the climatic system, with the primary source of increased CO2 being from fossil fuel use. Warming of the climatic system is undoubtedly happening, as is now evident in; increases in average global air and ocean temperatures; widespread melting of snow and ice; and rising of global mean sea level. Furthermore, more intense and longer droughts have been observed over wider areas since the 1970s - particular in the tropics and the subtropics. The frequency of heavy precipitation events has increased over most land areas, consistent with warming and observed increases in atmospheric water vapour. All these trends are considered very likely to continue in the coming years.

It is obvious that such changes will have direct impacts on water management issues, including those related to water supply and irrigation (such as increased droughts and melting glaciers), as well as to human safety and health (such as increased flood risks and waterborne deceases). It is expected that by the mid-century, average annual river run-off may decrease

[25] IPCC (2007): Climate Change 2007: The Physical Science Basis. IPPC Secretariat, Switzerland
IPCC (2007): Climate Change 2007: Impacts, Adaptation and Vulnerability. IPCC Secretariat, Switzerland

by 10-30% in some dry regions at mid-latitude and in dry tropics - some of which are already water-stressed areas. Furthermore, many millions more people are projected to be affected by floods every year due to rising sea-levels, with small, low lying islands considered to be especially vulnerable.

IPCC believes that there is a high probability that recent regional changes in temperature have had discernable impacts on many physical and biological systems. These changes have been documented in numerous studies in the northern high altitude ecosystems, for both inland and marine systems[26]. There is also a high probability that the resilience of many ecosystems is likely to be exceeded this century by an unprecedented combination of climate change, associated disturbances (e.g. flooding, drought, wildfire, insects and ocean acidification), and other global change drivers (e.g. land use change, pollution, and over-exploitation of resources. IPCC states that for increases in global temperatures exceeding 1.5-2.5 degrees Celsius, projections show major changes in ecosystem structure and function, with predominantly negative consequences for biodiversity and ecosystem goods and services.

Increased desertification in the Sahel will destroy the livelihoods of millions of poor herders and farmers. At present there are thought to be 30 million environmental refugees, who have been forced away lands where productivity has collapsed.

At lower latitudes, especially seasonally dry and tropical regions, crop productivity is projected to decrease as a result of local temperature increases of 1-2°C. This would increase the risk of hunger, particularly in areas reliant on rain fed agriculture. Regional changes in the distribution and production of particular fish species are expected due to continued warming, with adverse effects on aquaculture and fisheries in both inland and coastal waters. Coastal wetlands including, salt marshes and mangrove forests are projected to be negatively affected by a rise in sea levels.

These impacts will add to the direct environmental costs mentioned above, and in many cases these costs are expected to be very substantial. Unfortunately, the present knowledge and understanding of these ecosystem changes is not sufficient to determine the particular local impacts with much reliability. This is particularly true when it comes to the tropical and subtropical ecosystems of developing nations. There is an urgent need for the collection of data as well as the experiences and observations of the populations affected; in order to better detect and understand specific impacts. Efforts to address this truly global problem at its source are beyond the reach of individual countries and regions. With respect to water management, the recommended national response would be to develop improved monitoring frameworks for detection of critical changes; as well as to make climate change impact assessments of important water management policies and strategies. Prediction show that the global warming will continue, and only by developing efficient adaptation strategies today may the worst damage of adverse impact be mitigated in the future.

[26] See, for example, Drinkwater, K.F. (2005): The response of Atlantic Cod (Gadus morhua) to future climate change, ICES Journal of marine Science, 62: 1327-1337.

5.4 Balancing benefits and costs of Ecosystem assets

As argued above, environmental sustainability of specific policies and activities may be improved through consciously and transparently balancing all benefits and cost. In many cases, this may done politically via dialogue and consensus making. But often, economic conflict of interest call for a more quantifiable approach, by comparing economic (and/or possible other) values of the benefits and losses. Numerous technical papers have been written about establishing economic values and payments for ecosystem assets. But the ground rule is to start with a general – often qualitative – appreciation of the value of the EGS's under pressure, versus the gains from the activities creating the pressures. And to create a public and political understanding of the need to embed EGS in policy and decision-making. This may be done via two closely related approaches: Payment for Ecosystem Services (PES) and Marketing Ecosystem Goods and Services (MEGS)

Providing Payment for Ecosystem Services: PES

Subsequent to the introduction of the concept of ecosystem services, there has been considerable efforts to develop and apply PES schemes[27]. Generally speaking, the schemes focus on upstream-downstream issues and make an economic value assessment of the upstream services provided for a downstream user. This value becomes the price the downstream users have to pay to the upstream "service providers"

Sellers of ecosystem services

In particular, they have been applied to watershed management, where upstream landusers provide downstream water users with agreed flow and water quality. A formal agreement is established between the two parties and the downstream beneficiaries transfer payments to the upstream users. Experience shows that such a mechanism may be efficient, if there are clear and enforceable rules and transaction mechanisms, supported by good governance of the institutional framework. However, a general weakness of PES schemes is the difficulty in establishing fair and transparent payment procedures.

A more traditional and well-tested scheme has been the application of targeted Government Green Subsidies and Taxes. Such instruments have been effective in the EU, but experience also show that they may be suddenly revoked, when economic or political conditions change. Also, the administrive burden of such schemes is considerable. An alternative may be to apply a Environmental Degradation Tax (EDT) as an – almost negiligible – addition to the general Value Added Taxes (VAT). The revenue may then be put in a Government fund to provide PES and other incentives to land users and others in their efforts to protect ecosystem assets.

[27] See e.g.
DIIS (2007) http://www.diis.dk/graphics/Publications/Reports%202007/hmr_payment_for_eco_web.pdf
UNECE (2005): http://www.unece.org/env/water/meetings/payment_ecosystems/seminar.htm
Smith, M., de Groot, D., and Bergkamp, G.(2006) Pay. Establishing payments for watershed services. IUCN, Gland, Switzerland,.

Trading in Markets for Ecosystem Goods and Services: MEGS

General speaking, the PES approach often imply a heavy administrative overhead, as the ecosystem services are provided as well as used by large groups of people. PES needs strong monitoring and management, and in many cases, this will not be available.

To address this weakness, an emerging further development of the PES approach has recently been summarized by a group of environmental NGO's in cooperation with Shell International Limited. The general idea is to create markets and businesses as a tool to increase incentives and raise sources of finance for maintaining EGS[28]. Modern economies are not good of preserving the priceless. But they are very good at delivering what people will - or learn to - pay for. This radical but also controversial approach will use the same economic mechanisms that have been a major root cause behind the ecosystem depletion: Through establishment of Markets for Ecosystem Goods and Services (MEGS)

The idea is not new in environmental management, and it has been extensively applied in the CO2 trade system as a tool for climate change abatement. Many positive and negative experiences have been collected here, and these may serve as inspiration to a similar (but likely significantly modified) approach in a H2O trade system, where H2O includes not only water volumes but also ecosystem goods and services. The objective is to enlist the purchasing power of consumers and the productive capacity of business to help protect the ecosystems, we all depend on.

Sellers of ecosystem goods

It appears that there are numerous pro-ecosystem bussinenss opportunities related to water management issues, which may generate positive financial returns as well as actual ecosystem benefits. Obvious cases include markets for "Green Products" from organic agriculture, sustainable ranching and fisheries, natural herbs and fibers from wetlands. Or "Ecotourism Ventures" in its true and adventurous form. More complex trade processes for wetland and soil products and services may be used in pollution control, flood remediation, carbon sequestration and catchment protection.

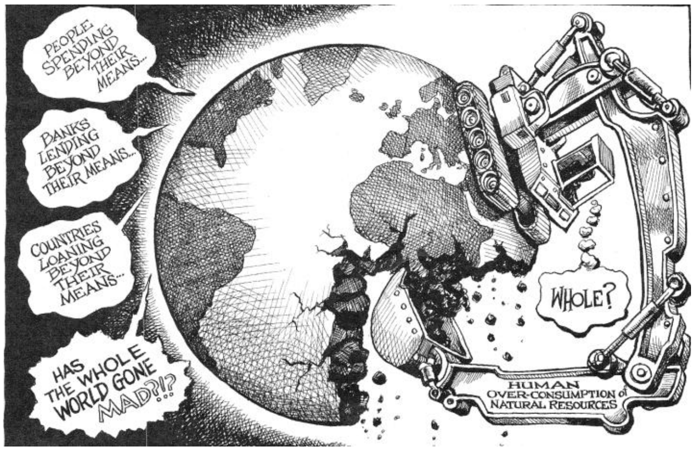
There is an apparent opportunity to raise substantial financial resources for ecosystem protection, if just a minute fraction of the global business investments can be channelled into such niche sectors. Undoubtedly, it will take substantial development efforts and also initial Government support in order to minimize risks and to ensure that new businesses survive long enough to be commercially viable. Such support may possibly be taken from Green taxes described above.

Also, there is a need to provide institutional frameworks to provide risky business investment and to assess and document the actual impacts in the ecosystems, and to provide reliable certification and monitoring systems to minimize fraud. And last but not least, it will have to

[28] See e.g.. Bishop, J., Kapila, S., Hicks, F., Mitchell, P. and Vorhies, F. 2008. *Building Biodiversity Business.* Shell International Limited and the International Union for Conservation of Nature: London, UK, and Gland, Switzerland.

promote synergies and cooperation between the water and ecosystem managers and the appropriate business sectors

6. Key Messages



Major constraints and obstacles have to be surpassed if the continuing degradation of the Worlds ecosystems shall be reversed. The challenges are of the same magnitude and complexity as found in climate change abatement, but unfortunately, it has not received the same public and political attention.

In relation to the mandates of UNEP and its Governing Council, the following messages may serve as inspiration for further action:

Water resources must be seen as much more than river discharge and water quality because.

- Surface water ecosystems provide crucial goods and services for the poor, in the form of crops, fish, timber and fiber. These assets are rarely accounted for.
- Estuarine and coastal waters are critically dependent on upstream flow conditions. Water management does nor stop when water becomes brackish and saline
- Soil water is a crucial management issue in rainfed agriculture with important implications for hunger and poverty alleviation.

IWRM and ESA will both benefit from a cross-fertilisation of concepts, approaches and practices because:

- IWRM has its entry points through *water* and land management. Environmental sustainability is a fundamental cornerstone of IWRM, but in practice, it has been primarily been focusing on nature conservation, more than a development asset. Fundamental issues such as fisheries are hardly being considered ESA fills this gap by also considering management of *living resources* - with human beings as integral part. Furthermore, ESA has the entry point to management through the functions of the ecosystem, which includes processes that provide goods and services to satisfy human needs.
- An IWRM process takes its point of departure in the water development needs of the economic sectors, and strives to satify these as well as minimizing impacts on aquatic ecosystems. ESA starts the other way round out by looking at the functions of the ecosystems; and from there sets the requirements to the key determinants and in particular flow and quality regimes. IWRM processes can benefit from an in-depth exploration of the relationships between ecosystem functions and water resources. Likewise, ESA can benefit from the in-depth exploration of the relationships between water resources, governance and socio-economic development.

Present management approaches are not sufficiently effective in protection of EGS. New approaches have to be developed because:

- Ecosystem concerns are often considered as a burden to water development policies and projects, not as en asset. It is necessary to provide politically convincing and tangible examples of the economic development and poverty alleviation potential in ecosystem goods and services

- There is a need to generate additional and self-sustainable funding for ecosystem protection. National funding, development assistance and private philanthropy is insufficient. A market-based approach – learning from the approaches to climate change abatement – may be developed and tested. Such an approach calls for institutional reform with cooperation between water experts, ecosystem biologists, land- and water users as well as the provate busines sector

The numerous "integrated" management approaches should be jointly assessed by the ESA approach and merged into one joint effort on INRM: (Integrated Natural Resources Management) . because:

- There is an administrative trend to redesign Minstries of Environment into Ministries of Natural Resources to be able to handle the issues of environmental sustainability.
- A narrow thematic focus on water, (or on land or on ecosystems) does not account sufficiently for the complexities and the inter-linkages in the field
- There is a need to include more management experts from the social science community

Annex 1: Starting implementation on environmental aspects of IWRM

Introduction

Any national or local approach for including - or more likely improving - the consideration of environmental aspects in IWRM must take as its point of departure the actual situation and progress in implementing IWRM. A full accounting of environmental assets as described above may be inappropriate as a first step when seen in relation to the often most pressing needs for water supply and sanitation, public health, flood protection and irrigation provision. But it should be emphasised that in many cases, user interests coincide with the environmental issues, providing clear benefits as opposed to acting as constraints. Also, many possible mistakes may be identified up-front through the more comprehensive approach, reducing later conflicts and costs to remediate unforeseen impacts.

One common constraint in including environmental aspects is the general lack of data or even understanding of the basic processes to form the “scientific” basis for water management. However, this should not deter the water managers from proceeding as long as the implementation strategies are robust and adaptive, and, as long as implementation goes hand-in-hand with proper monitoring and targeted research programs as an integrated component of the implementation activities.

The following suggestions for accelerating the process of mainstreaming environmental issues in IWRM planning and implementation should not be considered as anything else but an indicative list of ideas. The ideas may be modified, rejected or replaced by others. The start may be modest, as long as the basic objective is maintained: To find a balance between major benefits and impacts (costs) in the development and management of the nation’s water resources.

What to do?

Some general considerations recommended to address a particular issue in an IWRM reform strategy include:

- Mapping and focusing on environmental water issues, not only institutions or instruments;
- Building on existing administrative and user organisations – making reform, not revolution;
- Making a causal-chain assessment of key environmental priority issues related to the appropriate approach in the specific context;
- Obtain consensus among stakeholders on priority issues and causes;
- Developing a long-term strategic approach to address the reform process (The IWRM 2005 strategic plan): allocating resources for ”winning the war” against the key environmental water issues, and;
- Making short-term tactical action plans: planning to win next years battle in accordance with opportunities.

The lead agency

Introducing and implementing IWRM reform is first and foremost teamwork between authorities, water users and the supporting stakeholders in academia, NGOs and the private business sector. However, no task as complex as water management reform can be carried out successfully without clear leadership. If we take as our point of departure the “water as asset” approach, leadership may be vested with a parallel body to the Ministry of Finance, which is responsible for managing the fiscal assets of the nation. In the case of water resources assets, the leadership may be placed in a national apex body for water resources management. But it is important to have clear operational roles of the environmental and natural resource authorities, in particular to ensure checks and balances through safeguards and environmental audits.

The lead agency should be responsible for promoting politically viable approaches and strategies for enhancing the environmental sustainability aspects of developing the goods and services of the national waters. This involves an obligation to change the minds and attitudes of many decision-makers and user groups from a monopolistic "control and command" approach to a consensus-oriented "request and respond" approach. In particular, the lead agency must be independent of vested user interests to make it serve as an honest and fair broker in all matters related to the integrated development and management of water resources.

The supporting authorities

To re-emphasise, given the complexities inherent in water resources management, no authority will be able to successfully carry out the IWRM related tasks by itself. Cooperation through a network of the most important water authorities is essential, not necessarily in a fixed and bureaucratic commission structure, but possibly through issue specific task forces.

In particular, it is important to promote linkages and mainstreaming on national and local development objectives - at both macro and sector levels - relating to:

- economic development (macro policy as well as sectoral policies)
- social development (poverty alleviation, health, education, decentralisation)
- environmental sustainability, with emphasis on water security and ecosystem productivity

Additionally, environmental and natural resource authorities in various ministries need to join hands to introduce more comprehensive governance instruments, such as:

- Revisions of environmental policy and law
- Institutional collaboration and coordination with sector authorities – both horizontally and vertically
- Innovation in management instruments (impact assessments, strategic planning, regulation, establishment of audits and safeguards, incentives and taxes, market approaches, user mobilisation, conflict resolution, etc.)

Some possible catalytic activities

Implementing IWRM reform is a long-term process, often lasting for decades to reach the final vision. Implementation is highly dependent on political, social and economic contexts and opportunities, and extremely difficult to control by a traditional long-term approaches and action plans. The most appropriate approach may be to establish the general strategic scope of the process and then start with a few catalytic activities by picking the "low-hanging fruits".

Possible examples of catalytic initiating activities may be:

- Strengthening of multi-stakeholder national IWRM networks and partnerships with focus on awareness-raising and advocacy on environmental aspects in IWRM, including:
    - Government authorities responsible for economic and social development
    - Water managers in government
    - Water users in river basins

- Business sector entrepreneurs
- Supporting institutions like universities and NGOs

- Promotion of multi-stakeholder dialogues[29] on reform strategies:
  - Formulation/re-assessment of national strategic approaches to the IWRM reform process
  - Defining environmental aspects in national IWRM reform:
    - Key environmental water issues, their sectoral causes, management constraints and stakeholder concerns and interests
    - Environmental visions and quantitative goals, quantitative sectoral targets, management reform initiatives and responsible lead institutions
    - Assessing ecosystem value with scarce information
- Capacity development in appropriate stakeholder groups:
  - Training of champions and trainers in Government
  - Awareness-raising through public campaign in the media
  - Support of creation of a "Green Business" sector
  - Reform and development of relevant school curricula
  - Multi-disciplinary research programs on specific issues, in particular related to valuation of ecosystem assets
  - Bridge-building between the various scientific and administrative communities (water, lakes, coasts, catchments, soils, biodiversity, etc.)

[29] The Environment Times (2005): Can environmental assessment reduce poverty. See http://www.environmenttimes.net/article.cfm?pageID=208

Annex 2: Examples of Environmental Aspects of Water Sector Developments

A listing of water sector issues, their corresponding development issues and the associated environmental aspects is illustrated in Table 1 below. This table is a list for checking and identification of the most important issues in particular situations. It is provided here to make the guidance more comprehensive.

It is also important to emphasise that the responsibility for addressing these issues should not be solely placed within a Ministry of Environment or a Ministry of Natural Resources. Particular users should also be made equally responsible for addressing such impacts and make their contributions to sustainable development of the national and local economy as well as natural resources.

Table 1: Environmental Aspect Checklist

Water Sector	Development issues	Environmental aspects
Water and People	• Water supply • Sanitation	• Protection of the natural catchments providing drinking water • Maintenance of sufficient and reliable flows of the water supply source • Reduction of water borne diseases, such as diarrhoea, cholera, malaria, etc. • Protection of quality of water supply sources-- both surface and groundwater • Minimisation of the impacts of human wastewater discharges into both surface and groundwater • Minimisation of the subsidence impacts of groundwater development
Water and Food	• Agriculture development • Fisheries development	• Protection of natural catchments providing water to irrigation systems • Protection of aquifers providing water for irrigation • Protection of the water storage capacity of agricultural soils for rain fed agriculture • Maintenance of sufficient and reliable flows for irrigation systems • Protection of irrigated lands against salinisation • Reduction of nutrient and pesticide losses from agricultural lands to surface water and groundwater • Reduction of pollution emissions from high-intensity production systems like aquaculture, pig-farming, feed lots, etc. • Protection of the biodiversity and productivity of watersheds, floodplains, rivers, lakes, wetlands and coastal waters

Water Sector	Development issues	Environmental aspects
Water and Nature	Restoration and protection of the health, productivity and biodiversity of wetlands	• Ensuring environmental flow regimes in valuable river systems and associated wetlands • Maintaining appropriate river morphology in accordance with the needs of particular species • Reducing ecological impacts of point and non-point pollution sources in river systems and in coastal waters • Reducing environmental impacts of forestry and land use changes • Minimising salinity changes in estuaries and groundwater aquifers
Water and Industry	• water supply • industrial waste water discharge • groundwater contamination	• Protection of natural catchments providing water for industrial uses • Protection of aquifers providing water for industrial purposes • Maintenance of sufficient and reliable flows of the water supply source • Increasing water savings in production systems • Protection of the quality of water supply sources --both surface and groundwater • Minimisation of impacts of industrial wastewater – including cooling water discharges into both surface water and groundwater • Minimisation of the subsidence impacts of groundwater development
Water and Energy	• Hydropower • Cooling water discharges from thermal and nuclear power plants	• Regime changes in natural variation of flow due to energy demand controlled releases • Evaporation losses from reservoirs • Fisheries management in reservoirs • Hindrance of passage for migratory fish species • Temperature changes from deep water releases • Temperature impacts from cooling water releases of thermal energy systems
Water and Transportation	• Dredging • Blasting of rapids • Channelling • Sluice gates	• Changes in river morphology due to dredging and removal of rapids • Hindrance of passage for migratory fish species • Impacts on river flow regimes and low

Water Sector	Development issues	Environmental aspects
		flows • Pollution by spills
Water and Hazards	• floods, • storm surges • dam breaks • industrial accidents	• Changes in flow regime and sediment characteristics due to flood reservoir management • Exploitation of natural flood retention properties in floodplains and wetlands • River impacts due to construction of levees and flood release structures • Protection against impacts from industrial accidents like spills, fires, explosions, flooding, etc.
Water and Climate	• Air and water temperature increases • Changes in rainfall patterns and variability • Changes in ocean currents and temperatures	• Water shortages • Changes in monsoon patterns • Increased floods, hurricanes and storm surges • Prolonged drought • Desertification • Ecosystems changes