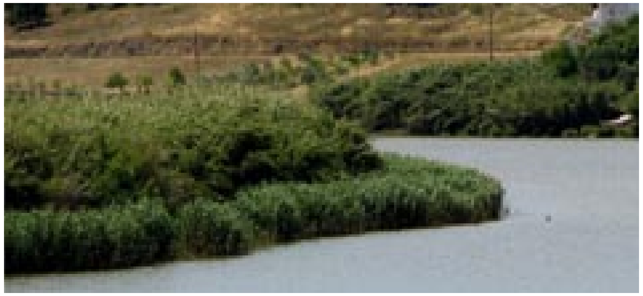
DEMONSTRATION PROJECTS

Integrative Science to Solve Issues Surrounding Water, Environment and People

ECOHYDROLOGY



The decline in water quality and biodiversity, observed at the global scale in both developed and developing countries, has provided evidence that conventional approaches to water resource management, based on application of engineering techniques, sectoral interventions and the elimination of direct threats such as point source of pollution, are important but not sufficient. Purely technical control, without understanding and considering biotic dynamics, is a more trial and error approach to water management than the implementation of techniques that better respond to policies aimed at sustainable water use and social development.

Ecohydrology uses the relationships between hydrological processes and biotic dynamics for sustainable water resources management at the basin scale

At the present level of human impacts on ecosystems, it is necessary to increase the opportunities for environmental restoration and wise management of water resources. This can be achieved by optimizing the absorbing capacity of ecosystems against human impacts. Such an approach must be based on an understanding of the temporal and spatial patterns of water and biotic dynamics at the catchment scale. Ecohydrology represents a new approach to freshwater resource restoration and sustainable management and provides an additional tool to manage the degradation of ecological and water processes in the landscape.

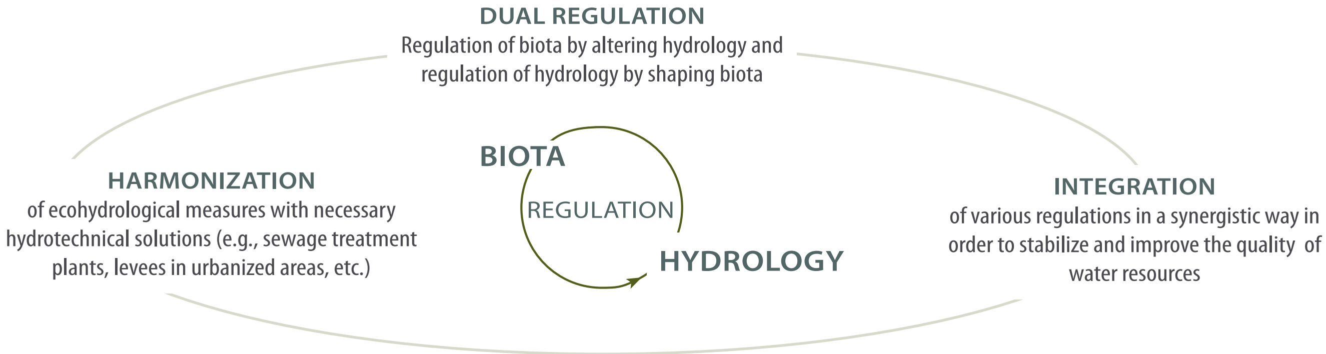
UNESCO's Ecohydrology Approach

The ecohydrology approach is based upon the assumption that sustainable water resources management can be achieved by:

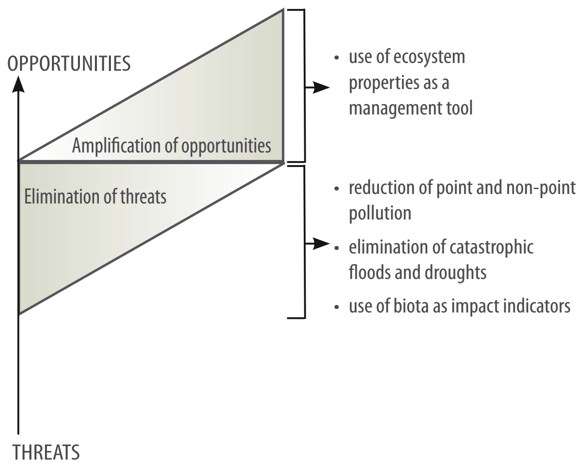
- restoring and maintaining at a catchment scale well-established water circulation patterns, nutrient cycles and energy flows;
- enhancing the carrying capacity of ecosystems against human impacts by managing them according to ecosystem properties;
- using ecosystems as a water management tool.

Ecohydrology uses the dual interactions between biota and hydrology to regulate, remediate and conserve ecosystems. Moreover, synergistic effects of various ecohydrological measures stabilize and improve the quality of water resources. Implementation of ecohydrology is undertaken through "harmonization" with existing and planned hydrotechnical infrastructures.

Key assumptions of ecohydrology



Application of ecohydrology as a factor maximizing opportunities of sustainable freshwater management



Modified from Zalewsky, 2002

Demonstration Projects in Ecohydrology

The growing demand to provide evidence of successful implementation of ecohydrology solutions calls for a worldwide network of demonstration projects. This is also necessary in order to validate and quantify the effectiveness of ecohydrological solutions.

The objectives of the demonstration projects in ecohydrology are:

- demonstrating the application of the ecohydrology approach to solve issues surrounding water, environment and people;
- contributing to the development of research on ecohydrology, increasing scientific knowledge to implement integrated watershed management and identifying solutions for sustainable development in ecological and social systems in which water acts as a main driver;
- qualitative and quantitative validation of the effectiveness of the ecohydrological approach in practice, using methodologies identified by members of UNESCO's Scientific Advisory Committee on Ecohydrology and participating scientists.

Danube River, Lobau floodplain, Austria
University of Vienna, Austria

Guadiana Estuary, Portugal
University of Algarve, Faculty of Marine Sciences and Environment, Centre for Marine Sciences, Portugal

Lacar Lake, Huahum River Basin, Patagonia, Argentina
National University of La Plata, Argentina

Lake Naivasha, Kenya
Lake Naivasha Riparian Association, Kenya
University of Leicester, UK

Mara River & Serengeti Plain, Kenya & Tanzania
Tanzania National Parks
Australian Institute of Marine Science

Paraná Floodplain, Brazil
Universidade Estadual de Maringá, Brazil

Pilica River, Poland
University of Lodz, Poland
International Centre for Ecology, Polish Academy of Sciences

Saguling Reservoir & Citarum River, Indonesia
Indonesian Institute of Science

Amazon River Floodplain, Brazil
Instituto Nacional de Pesquisas da Amazônia (INPA), Brazil
Max-Planck-Institute for Limnology, Germany

The Polesie Region, Belarus, Poland and Ukraine
National Academy of Sciences of Belarus
International Centre for Ecology, Polish Academy of Sciences
National Academy of Sciences of Ukraine

Demonstration Projects to Address a Wide Range of Issues

Saguling Reservoir & Citarum River, Indonesia:

Study of urban and industrial pollution and reduction of sedimentation by controlling hydrological dynamics

Major reservoir functions are flood protection, hydropower generation and potential water supply. Urbanization, improperly treated urban and industrial sewages, agriculture, deforestation and fish cage culture have reduced water quality. Application of hydraulic modeling will enhance sediment trapping in the mouth of tributaries. Internal loading in the reservoir will be reduced by sediment removal and their use for agricultural field fertilization. The project will increase environmental awareness of local communities through education.

Mara River & Serengeti Plain, Kenya & Tanzania:

Water deficit and inter-basin transfer of water resources for large mammals migrating to Serengeti (UNESCO World Heritage Site and MAB Biosphere Reserve)

The Mara River Catchment is a dry weather refuge for more than 1 million migrating wildebeest and zebras of the Serengeti ecosystem. In Kenya, deforestation, water diversion and hydropower distress river hydrological stability, biodiversity and thus the economic base of communities. Reforestation, forest conservation and use of existing and new wetlands will restore the hydrological cycle. A management plan based on a mathematical model will be produced.

Danube River, Lobau floodplain, Austria:

Hydrological regime optimization to maintain biodiversity in the Lobau Biosphere Reserve and flood protection for Vienna

The goal is the optimization of the river's hydrological regime to maintain biodiversity. Potential conflicts are foreseen with the planned hydrological flood-protection that may increase sedimentation and reduce biodiversity in the floodplain. Solutions include strengthening ecosystem services by providing alternative habitats for the abundant and diversified macrophyte vegetation.

Lake Naivasha, Kenya:

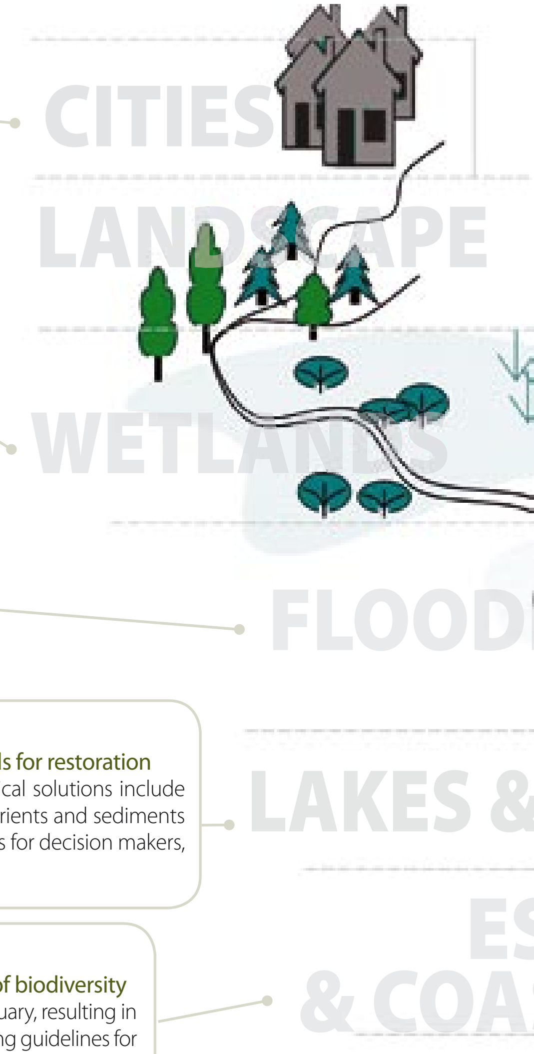
Re-creation of artificial Cyperus papyrus wetlands surrounding the lake and at inflowing river deltas using phytotechnological methods for restoration

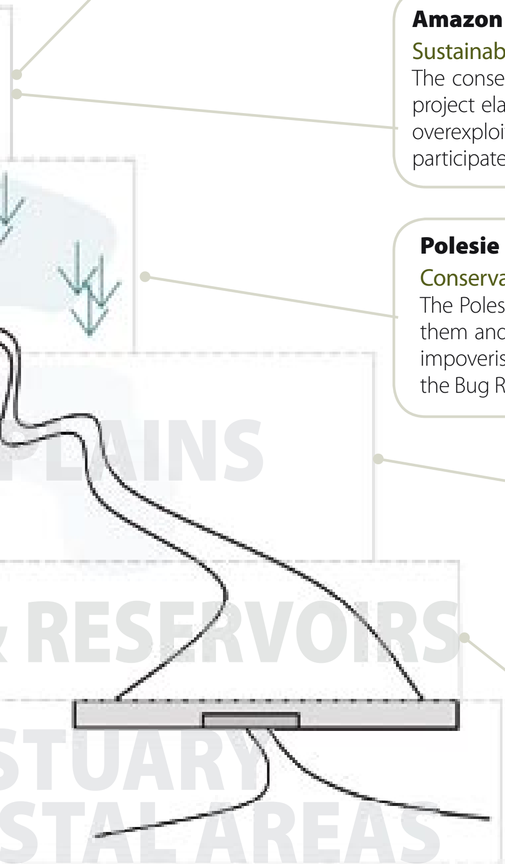
The major stressors for the lake are increased sediment and nutrient inputs, biodiversity loss and habitat degradation. Proposed ecohydrological solutions include mitigation of further pollution by catchment reforestation, re-creation of a papyrus buffering zone around the lake's shoreline, and trapping nutrients and sediments from rivers using sequential wetlands during different discharge regimes and hydrographic stages. The project includes educational programmes for decision makers, stakeholder and local communities.

Guadiana Estuary, Portugal:

Sustainable estuarine zone management for control of eutrophication, toxic blooms, invasive species and conservation of biodiversity

Construction of the Alqueva Dam across the upper Guadiana River affected nutrient ratios and sediment loads transported to the estuary, resulting in eutrophication, toxic algal blooms, decreased biodiversity and marshland degradation. These processes can be mitigated by developing guidelines for optimizing pulse-patterns of water discharge from the reservoir. Maintenance of good water quality and biodiversity will positively influence fisheries and tourism development in the area.





Lacar Lake, Huahum River Basin, Patagonia, Argentina:

Reduction of erosion in a catchment using ecohydrology and phytotechnology

The project is designed to contribute to the mitigation of floods in urban areas of San Martin de los Andes and improvement of ecosystem services (water quality and landscape aesthetic values). These can be achieved by regulation of surface hydrology in the catchment through vegetation cover management (phytotechnology), sedimentation and runoff control. Policies based on sound science will improve the management of land and water resources and reduce institutional and management conflicts.

Amazon River Floodplain, Brazil:

Sustainable timber production and management of Central Amazonian white-water floodplains

The conservation of biodiversity and genetic resources of tropical forests remains one of the most important ecological challenges today. This project elaborates an innovative concept for economically-efficient management of fast-growing plantations as an alternative for tropical forest overexploitation. Understanding the effects of flooding on tree growth will enhance plantation productivity. Local inhabitants will be invited to participate in the project design and receive technical training.

Polesie Region, Belarus, Poland and Ukraine:

Conservation and sustainable use of a transboundary wetland in the Polesie region (planned West Polesie Tranboundary Biosphere Reserve)

The Polesie transboundary region is a unique system of peat bogs, marshes and wetland habitats. Global climate change and variability has endangered them and has been amplified by land development and recreation. A significant decrease of surface and ground water levels, increased eutrophication, impoverishment of species and habitat diversity and reduction in biodiversity resulted. Water retention enhancement by improving connectivity between the Bug River valley and adjacent habitats will be designed for compensation of global climate change effects.

Paraná Floodplain, Brazil:

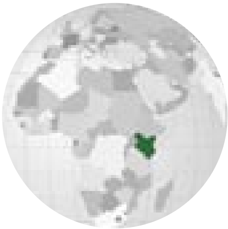
Creation of a biosphere reserve to prevent decline in the unique subtropical river floodplain biodiversity

Creation of 26 large reservoirs in the basin altered the hydrological regime of the river, resulting in modified ecosystem structure and functioning and decreased biodiversity. Adjustment of operational procedures for water outflow from the Porto Primavera Dam to ecological cycles can restore these processes without significant hydro-energy production loss. Maintaining biodiversity and ecosystem services will create income for local populations (e.g., fisheries and tourism) and lead to the creation of a MAB biosphere reserve.

Pilica River, Poland:

Application of ecohydrology and phytotechnology for water resources management and sustainable development

The project develops an ecohydrological approach to mitigate toxic algal blooms in a lowland reservoir recreational area and an additional drinking water supply for a city of 800,000 inhabitants. Understanding the relationships between hydrological patterns of the reservoir's tributaries and nutrient transport is a basis for reducing nutrient loads. Optimization of floodplain hydraulics maximizes nutrient retention by both physical sedimentation and conversion into biomass that can be used as bioenergy, providing alternative income for local communities.



Re-creation of artificial Cyperus papyrus wetlands surrounding the lake and at the deltas of inflowing rivers: Basin-wide phytotechnological methods for restoring biodiversity, the hydrological regime and hydrochemistry

Project Coordination: University of Leicester, Lake Naivasha Riparian Association

Lake Naivasha, Kenya

Key environmental issues: eutrophication and modification of the hydrological regime

Catchment degradation: Deforestation of the upper catchment; Intensive erosion of steep slopes in the middle catchment and loss of the buffering capacity of river riparian strips; Abstraction in excess of recharge of the system's surface water and groundwater, leading to lake volume decline; Land clearance for industrial agro-horticulture; Lake shoreline destruction by the local population (swollen to 1/3 million by the draw of employment in horticulture) using the lake for domestic water supply and stock watering.

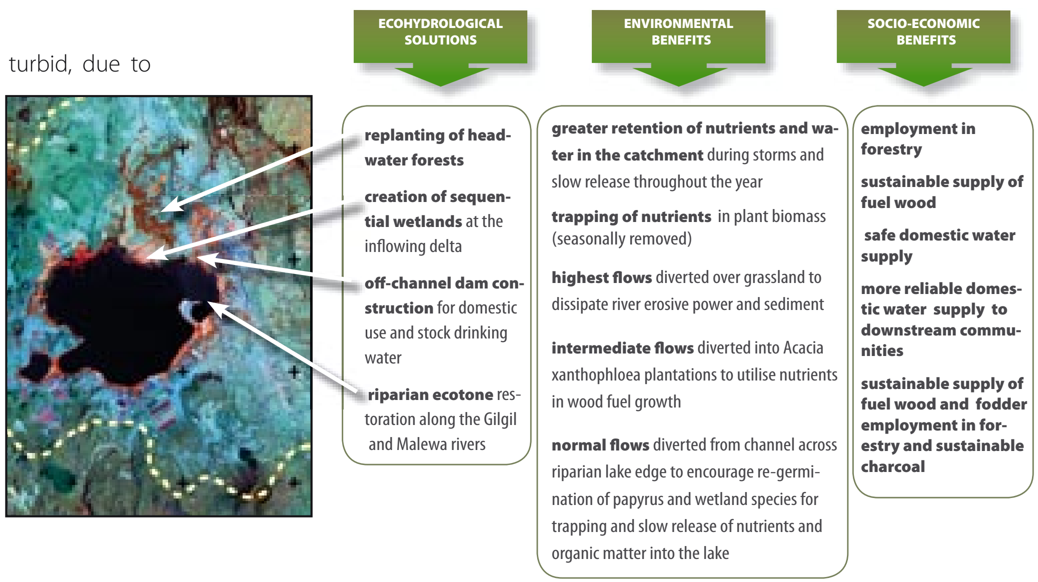
Lake ecological conditions: Ecological conditions in the lake have deteriorated considerably since 1980. The Cyperus papyrus riparian vegetation protecting the lake from diffuse pollution has declined from about 60 km^2 to <10. The native floating-leaved and submerged vegetation are severely endangered as a consequence of an alien species (Louisiana crayfish) introduction.

Lake water quality: The lake is now very turbid, due to the increased levels of nutrients promoting phytoplankton growth. The blooms do not presently include cyanobacterial dominants, although toxin-forming species are present in the phytoplankton assemblage. Most of the nutrients come in from the permanent catchment river (Malewa) bringing silt from the north, and the seasonal streams from the south bringing eroded sediment from heavy settlement and horticultural activities.

Socio-economic issues: The economic value of the lake is derived mainly from a considerable horticulture industry around the lakeshore, dependant on rich, volcanic soils, an equatorial climate and availability of freshwater for irrigation. Other uses include tourism (due to interest in the area's biodiversity) and fisheries.

Applying ecohydrology

A combination of several ecohydrological and phytotechnological measures is proposed: 1) Promotion of upper catchment re-afforestation by the horticultural industry to restore runoff. 2). Re-creation of shoreline papyrus, particularly at the delta region, where the innovative ecohydrological approach is the design of new inflow swamps for sequential trapping of nutrients and sediments from rivers at different discharge regimes. 3) Plantation of fast-growing (native) Acacia woodlands in the riparian zones to restore biodiversity and provide sustainable fuel. 4) Educational programmes for the local stakeholders and communities, including training and production of video/DVD material. The application of this programme in a developing country with limited monetary resources will demonstrate a "low cost – high technology" solution to sustainable water management.



Saguling Reservoir and Citarum River, Indonesia

Key environmental issues: water quality deterioration and water supply fluctuations

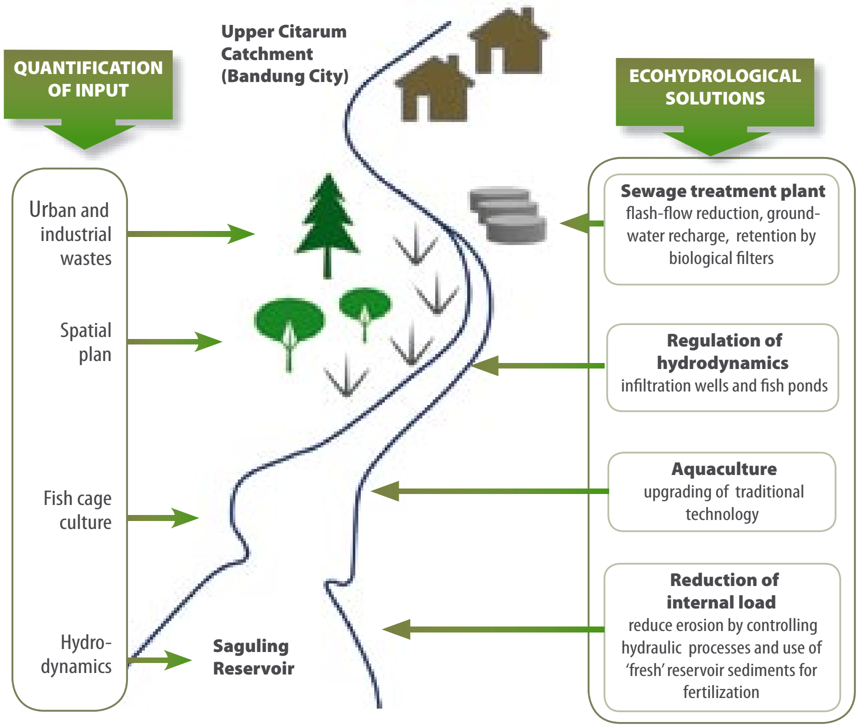
Deterioration of water quality: the reservoir provides irrigation water and drinking water to the capital of Indonesia, Jakarta. Eutrophication and toxic algal blooms have restricted this function. Pollution originates mainly from the upper catchment and mostly from improperly treated urban and industrial sewage, agriculture and land-use transformation due to urbanization and deforestation. A significant nutrient source for eutrophication is the internal load from the sediments that intensively accumulate at the bottom of the reservoir from the ever-expanding traditional fish cage culture.

Changes of water levels: An increasing trend of high water supply fluctuations from the catchment between wet and dry seasons restricts continuous hydropower generation. Water deficiency during the dry season disrupts hydropower generation, resulting in the application of costly rain-harvesting techniques.

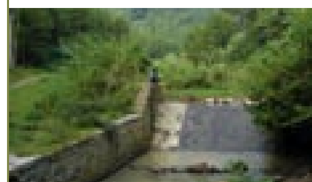
Socio-economic issues: Reservoir degradation is rooted in socio-economic problems. According to studies in the upper catchment, this degradation is due to intensive population growth and untreated urban and industrial wastes. This could be steadily reduced by environmental education and information dissemination efforts by the demonstration project.

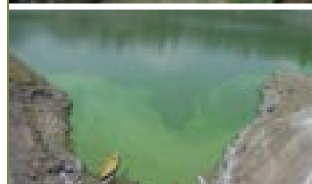
Applying ecohydrology

The integrated approach to catchment and river-reservoir management has to address several aspects. Hydropower generation requires stabilization of the hydrological cycle in the catchment by setting spatial planning and land-use regulations. Improving the quality of water requires several parallel actions, including wastewater technology for sewage treatment and ecohydrological methods. Hydraulic modeling will enhance sedimentation in controlled areas in the river mouth. The removal of sediments, which can be used for fertilizer by local farmers, will reduce internal nutrient loading. Particular attention will be given to increasing environmental awareness of local communities. This will result in the revision of traditional aquaculture technologies, reduction of environmental degradation (e.g., ecotone vegetation zone degradation, optimum fish-feeding technologies) and provision of economic opportunities (e.g., new farming opportunities).



Study of urban and industrial pollution and reduction of sedimentation by controlling hydrological dynamics





Project Coordination: Indonesian Institute of Science

Sustainable estuarine zone management for control of eutrophication, toxic blooms and invasive species, and conservation of biodiversity

Project Coordination:
University of Algarve

Guadiana Estuary, Portugal

Key environmental issues: eutrophication and modification of riverine discharge

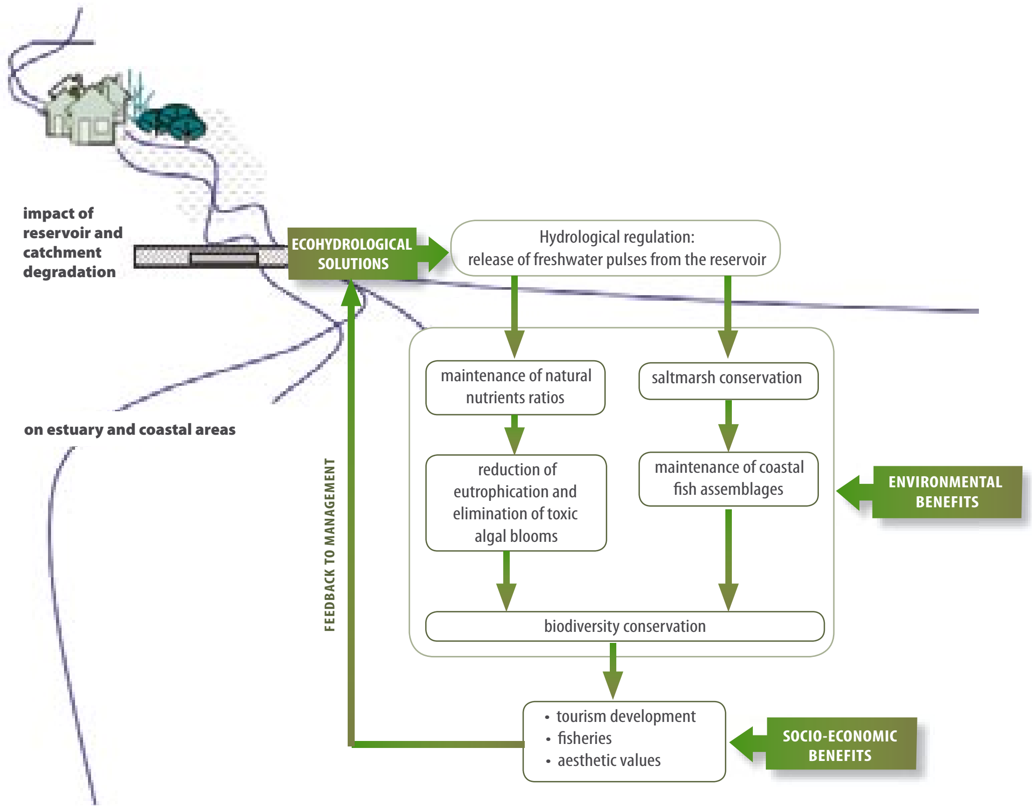
Salt marsh degradation and changes in biodiversity: The Alqueva Dam was constructed in 2002 to provide a strategic water reserve for human consumption, irrigation for developing agriculture and hydropower production. It affected riverine discharge and consequently the sediment, nutrient and freshwater inputs into the estuary and costal zone. Moreover, fine sediment load reduction and increased saline intrusion reduced nutrient and sediment trapping in the saltmarsh with negative impacts on the spawning and nursery uses of this area by several invertebrate and fish species. These processes modified species distribution and abundance, enhanced growth of exotics and reduced indigenous species, and thus affected biodiversity.

Water quality degradation: Several pollution sources, mainly from urbanization, agriculture (cattle breeding, orange and olive oil production) and ancient mines, contributed to the degradation of water quality of the upper estuary. Eutrophication and enhanced silica trapping in the reservoir resulted in decreased concentration in the estuary, supporting the development of non-siliceous algae, including toxic cyanobacteria and dinoflagellates.

Socio-economic issues: Toxic algal blooms and biodiversity changes affect estuarine and coastal zone fishing, aquaculture and tourism activities.

Applying ecohydrology

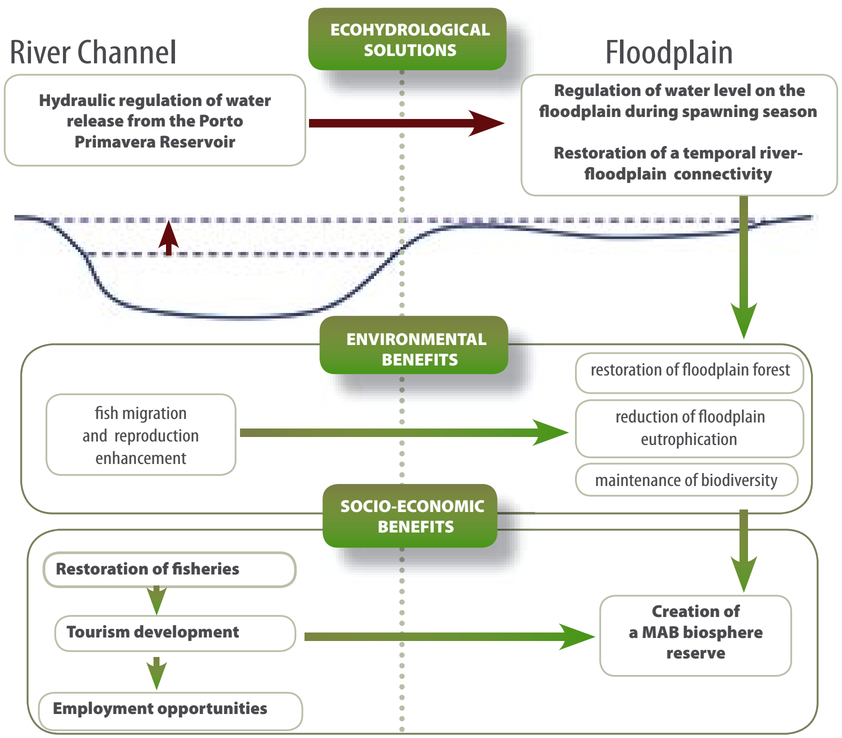
The approach will require specific technological development to match socio-economic and ecological problems stemming from river damming. Establishing a pulse-like discharge regime from the reservoir will restore natural nutrient ratios and restrict toxic blooms. Salt marsh area recuperation will improve water quality by promoting vegetation buffer zones and biodiversity restoration. Installing macroalgal floating systems near high nutrient inputs will additionally help improve water quality. The ecohydrological mathematical model developed for the Guadiana River and estuary will be used to assess the management impact on the ecosystem.



Paraná Floodplain, Brazil

Key environmental issues: river-floodplain disconnectivity due to river fragmentation

Floodplain degradation: The natural hydrological regime of the river has been changed due to construction of 26 large reservoirs (>100 km^2) for hydro-energy production in the basin. Reduction of the natural variability of the river discharge restricted connectivity of the river and floodplain, impacting water and nutrient exchanges. Sand extraction, an important income for local people, as well as drainage of the floodplain for rice farming and pastures, contributed to their further degradation and riverbed instability.



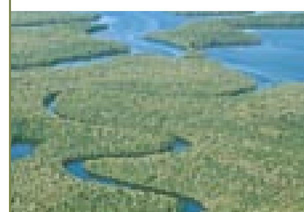
Biodiversity and water quality: Connectivity generated by flood pulses regulates nutrient exchange and productivity of aquatic communities and prevents floodplain eutrophication. Elimination of flood cycles not only increased eutrophication risk, but also modified the structure and functioning of the floodplain and river ecosystems by reducing breeding areas for many animals. Lack of connectivity due to reduction of high water levels restrains several species from dispersing in the floodplain and makes their local extinction more probable. This may severely affect the existence of rare species and lower biodiversity, which affects the robustness of the system.

Socio-economic issues: Use and exploitation of floodplain and river resources (sand extraction, agriculture, ranching, fisheries) provide the major income for local people. Ecosystem services, mainly those linked with eco-tourism, sport and recreation, play an increasing role in the local economy. Unsustainable floodplain management may negatively impact fisheries and reduce the appeal of the region for tourism, thus reducing the opportunities for such income-generation possibilities for local populations.

Applying ecohydrology

Elaboration of operational plans for hydrotechnical infrastructure has a great potential to maintain the flood cycle close to the natural regime and improve river-floodplain connectivity below the reservoir. The optimal regime should ensure high hydropower production while considering ecological cycles, enhance fish yield and preserve biodiversity. Ecosystem services will ensure income for local populations (e.g., fisheries and eco-tourism) and thus restrict damaging human activities in the remaining floodplain areas. Maintaining biodiversity will contribute to creation of a biosphere reserve (MAB) in the last stretch of the upper Paraná River basin in Brazil. Local populations will participate in the process of decision-making for floodplain preservation, environmental reconstruction and environmental education.

Creation of a biosphere reserve to prevent decline in the unique subtropical river floodplain biodiversity



Project Coordination: Universidade Estadual de Maringa

UNESCO and ecohydrology

Water quality degradation, overexploitation of freshwater resources, hydrological hazards and adverse effects of inappropriate management of water resources and ecosystems pose a risk to human health, economic and social development as well as to ecosystem functioning and the maintenance of ecosystem services on which human well-being depends. An urgent need for new concepts and solutions was recognized by the international community at the International Conference on Water and the Environment in Dublin in 1992. As a follow-up to this call, in 1996, UNESCO's International Hydrological Programme (IHP) launched an activity that focused on the integration of biological and hydrological processes at the catchment scale in order to develop the scientific basis for a new systemic and cost-effective approach to the integrated management of freshwater resources. The ecohydrology approach developed as the result of this activity is based on the assumption that ecosystem properties and water dynamics can be managed so as to maximize their synergistic interactions and to optimize ecosystems' resilience to human-induced stresses, while also reducing such stresses.

Activities under the fifth phase of the IHP (IHP-V:1996-2001) focused on the formulation of the principles guiding the application of the ecohydrology concept and took into account the experiences of the project under UNESCO's Man and the Biosphere (MAB) Programme on "Role of land/inland water ecotones in management and restoration of landscape". Activities under IHP-VI (2002-2007) focused on two major actions: strengthening the interdisciplinary character of ecohydrology by integrating it with other scientifically-related concepts and ecosystemic approaches; and verifying and validating the concept by applying it to solve existing problems affecting watersheds.

As part of the first above-mentioned action, a number of activities dealing with issues such as coastal areas and environmental toxicology began, and cooperation with organizations such as the International Environmental Technology Centre of the United Nations Environment Programme (UNEP-IETC) and the International Association of Theoretical and Applied Limnology (SIL) took place.

As part of the second above-mentioned action, UNESCO launched a network of demonstration projects, which address a wide variety of environmental and social issues. The projects will allow for the further testing, refinement and promotion of the ecohydrology approach among scientists, stakeholders and policy-makers. They will also enable the development of solutions to sustainable water management to be applied in different regions of the world.

In the future, the demonstration projects will facilitate the incorporation of social, political, economic and cultural factors into ecohydrology, by demonstrating the importance and the necessity of such factors on the ground, and thereby enable the solving of issues surrounding water, environment and people in a holistic manner.

The demonstration projects introduced in this brochure are being developed as part of the joint IHP-MAB work plan on "Managing land-water-habitat interactions through an ecosystem approach".

The European Regional Centre for Ecohydrology (ERCE) under the auspices of UNESCO opened in May 2006, in Lodz, Poland. The ERCE was established by the Government of the Republic of Poland in cooperation with the Polish Academy of Sciences and the University of Lodz. Other centres on ecohydrology are expected to be set up in Asia and Latin America, and the ERCE will work in close collaboration with them and other UNESCO water-related centres.

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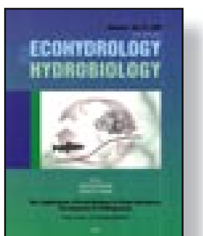
Codd G.A., Azevedo S.M.F.O., Bagchi S.N., Burch M.D., Carmichael W.W., Harding W.R., Kaya K., Utkilen H.C. 2005. CYANONET: A Global Network for Cyanobacterial Bloom and Toxin Risk Management. Initial Situation Assessment and Recommendations. UNESCO-IHP, Technical Documents in Hydrology No 76, Paris, 138 p.



International Journal - Ecohydrology & Hydrobiology

International Journal of ECOHYDROLOGY & HYDROBIOLOGY was launched in 2001. The Journal publishes papers concerned with the ecohydrology of rivers, reservoirs and lakes, with emphasis on the functional interrelations between hydrology and biota. It includes original research papers, reviews, short communications, book reviews and special issues integrating new research directions. www.ecohydro.pl

Ecohydrology and Phytotechnology Handbooks

(joint UNESCO-IHP and UNEP-IETC publication)

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UNESCO-IHP, UNEP-IETC. 2004. Integrated Watershed Management-Ecohydrology & Phytotechnology- Manual. Zalewski, M., Wagner-Lotkowska I. (ed.). UNESCO-IHP, UNESCO-ROSTE, UNEP-DTIE-IETC, ICE PAS, DAE UL, Venice, Osaka, Warsaw, Lodz. 208 p. www.unep.or.jp/ietc/publications/freshwater/watershed_manual.

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