

Understanding ecohydrological processes for sustainable floodplain management

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Introduction

In the 20th century, the global economic development was to a great extent achieved by exploitation of nature without considering the necessity to maintain the integrity of structure and processes of ecosystems, ensuring their services for future societies. According to NASA, over 80% of the Earth's surface, previously covered by various types of ecosystems, has already been modified by human activities, changing the environmental equilibrium of the Earth. Today we have 45,000 dams over 15 m high retaining about 15% of the total annual global runoff. Freshwater bodies, situated in the lowest points of the landscape, are exposed to cumulative impact of this steady degradation of hydrological and biogeochemical cycles in their catchments. Additionally, degradation of 50% of wetlands (RAMSAR), which constitute a natural buffer between the landscape and water bodies, has been lost due to land transformations, while rivers regulation and fragmentation (over 90% of rivers in Europe; WWAP), handicap their ability to cope with the stress, impairing their resilience and resistance.

Unsustainable catchment development and water bodies use often results from the old paradigm-driven management strategies, which do not take into account the ecosystems properties and catchment resilience. They are additionally spurred by increasing global impacts that are likely to grow more and more serious over the coming years (e.g., population growth, urbanisation, climate change; Wagner et al., 2008). If integrated and innovative management and restoration strategies are not widely accepted and adopted, there is a threat that the ability of freshwaters to provide ecosystem services will be seriously handicapped, while accompanied by still growing demands. This may impede the achievement of the Millennium Development Goals of the UN in developing countries, and the achievement of good ecological status of the Water Framework Directive of the European Commission in Europe. This situation therefore poses a challenge for both science and societies.

Land/water transitional ecosystems, such as wetlands, play a special role in this picture. Scientific research proves that average annual value of ecosystem services generated globally e.g., by floodplains is higher than those supported by other aquatic ecosystems. River floodplains also play an important role in compensating the global climate change through:

- increase of water storage and stabilization of ground and surface water levels;
- intense of CO₂ absorption by plant biomass production driven by favourable water and nutrient conditions;
- significant enhancement of self-purification of rivers and reservoirs and diminishing nutrient transport to coastal waters.

Ecohydrology

In the present situation, environmental protection and reversal of the degradation are not sufficient to maintain the global homeostasis and providing the required services. It is therefore necessary to concomitantly increase the „absorbing capacity” (resistance and resilience) of catchments against the impact. That is why the new measures for environmental management, towards sustainability and achievement the MDGs, have to be based on innovative methods applied to the regulation of ecological processes.

Such an approach is proposed by Ecohydrology, which is as a sub-discipline of hydrology focused on ecological aspects of the water cycle. It uses ecosystem properties and dual regulation between the hydrological and ecological processes in a catchment scale as a tool for water resources management. Ecohydrology (EH) has been developed over the lifetime of UNESCO IHP-V, 1996-2001 (Zalewski at all, 1997).

According to ecohydrology, sustainable development of water resources depends on the ability to maintain the ecosystem processes that have been established by evolution. These ecosystem processes regulate water and nutrient circulation and energy flow at the basin scale. The general question posed in the formulation of the concept of Ecohydrology concerns how to regulate the biological processes of freshwater ecosystems using hydrology; and - *vice versa* - how to use biotic ecosystem properties as a tool in water management. The syntheses of the concept, describing ecohydrology hypotheses, tenets and providing examples of applications were published in the “Guidelines for the Integrated Management of the Watershed – Phytotechnology and Ecohydrology” (UNEP, UNESCO 2002) and in the “Integrated Watershed Management-Ecohydrology & Phytotechnology- Manual” (UNESCO, UNEP, 2004).

The concept of Ecohydrology is based on the following principles, providing the framework, goal and methodology for the concept (Zalewski 2000, 2002):

1. Integration of catchment and biota into a Platonian superorganism to identify threats and opportunities resulting from the reversal of degradation of water and ecosystem resources, which covers such aspects as:

- scale - the mesocycle of water circulation in a basin (terrestrial/aquatic ecosystem coupling) has been a template for the quantification of ecological processes such as nutrient dynamics and energy flow;
- dynamics - water and temperature have been a driving force for terrestrial and freshwater ecosystems;
- hierarchy of factors - the abiotic processes are dominant (hydrology), however once they become stable and predictable the biotic interactions begin to manifest themselves.

2. Understanding the evolutionarily-established resistance and resilience of such superorganisms to stress

This aspect of Ecohydrology expresses the proactive approach for sustainable management of freshwater resources. It assumes that it is not enough to simply protect ecosystems by regulating or preventing human activities within them. Global changes which are associated with increase in population, energy, material and human aspirations are inevitable. It is therefore necessary to concomitantly increase the ‘absorbing capacity’ (resistance and resilience) of ecosystems against these human impacts.

3. The use of ecosystem properties as management tools

Ecosystem properties which have been used as management tools have been termed as Ecological Engineering (Mitsh 1993, Jørgensen 1996). Ecohydrology is a systemic approach implemented to IWRM. Its third principle is related to ecological engineering and defines how to enhance resilience and resistance of ecosystems in river basins based on tenets of ecohydrology. These have been developed based on the several years of cooperation by an interdisciplinary team of scientists involved in the UNESCO IHP:

1. DUAL REGULATION of hydrology by shaping biota and, vice versa, regulation of biota (eg., elimination of toxic algal blooms) by altering hydrology.
2. INTEGRATION – at the basin scale various types of regulations (E↔H) should be integrated towards achieving synergy to stabilize and improve the quality of freshwater resources at a basin scale.
3. HARMONIZATION of ecohydrological measures with necessary hydrotechnical solutions (e.g., dams, irrigation systems, sewage treatment plants, levees at urbanized areas etc.)

Case Studies

There is an increasing number of evidence confirming the effects of application of ecohydrology in broad scope of aspects related to water resources management. Among others, ecohydrology has been applied for enhancement of biodiversity (Agostinho, et al., 2001), fish production (Timchenko & Oksiyuk 2002), production of bioenergy, reduction of stable pollutants such as heavy metals and pesticides (Gouder de Beauregard & Mahy, 2002), socio-economic feedbacks in ecosystem (Zalewski, 2002, Wagner-Lotkowska et al., 2004), socio-economic feedbacks in urban areas for stormwater retention and sewage sludge utilization (Wagner et al., 2008).

Establishment of a network of Demonstration Projects on Ecohydrology (EH & HB Journal, 2004) has been one of the major actions undertaken by the Joint UNESCO IHP and MAB action in the last years. The network allows for testing the concept and its implementation throughout the gradient of geographic zones, climates, water-related issues and social contexts, addressing a wide variety of environmental and social issues. Ecohydrology has been implemented in a number of freshwater ecosystems, along a hypothetical river continuum and catchment, and transitional water/land ecosystems. Floodplains and wetlands, which are of crucial importance for the quality and health of freshwater ecosystems, as well as for the enhancement of catchments resilience, are widely represented in the network. Various aspects of floodplain ecohydrology have been developed by the following projects: the Pilica River, Poland (University of Lodz and ERCE u/a UNESCO), the Mara River & Serengeti Plain, Kenya & Tanzania (Tanzania National Parks and Australian Institute of Marine Science), the Danube River, Lobau floodplain, Austria (Vienna University), Lake Naivasha, Kenya (Lake Naivasha Riparian Association, Kenya and University of Leicester, UK), the Guadiana Estuary, Portugal (University of Algarve), the Amazon River Floodplain, Brazil (Instituto Nacional de Pesquisas da Amazônia – INPA - and Brasil & Max-Planck-Institute for Limnology, Germany) and the Paraná Floodplain, Brazil (Maringa University).

The demonstration projects allow for further testing, refinement and promotion of ecohydrology among scientists, stakeholders and policy-makers, and develop sustainable solutions to be upscaled and replicated in other regions of the world.

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