Ecohydrology & Hydrobiology 16 (2016) 26–32

Contents lists available at ScienceDirect

Ecohydrology & Hydrobiology

journal homepage: www.elsevier.com/locate/ecohyd

Review Article

Wetland ecohydrology and its challenges

Demin Zhou [a,b,*], Hong Zhang [a,b], Chengliang Liu [a,b]

[a] Base of State Key Laboratory of Urban Environmental Process and Digital Simulation, Capital Normal University, Beijing 100048, China
[b] Key Laboratory of 3D Information Acquisition and Application of Ministry of Education, Capital Normal University, Beijing 100048, China

A R T I C L E I N F O

Article history:
Received 3 February 2015
Accepted 17 August 2015
Available online 17 October 2015

Keywords:
Ecohydrology
Wetlands
Sustainability
Natural ecosystem

A B S T R A C T

Wetlands function through strong interactions between hydrology and ecology, and thus are central environments for ecohydrological research, including the development of the core theories of ecohydrology and the associated methodology. Human society has entered into the so-called "anthropogenic era", in which human actions are causing severe perturbations to natural ecosystems. The scientific approach of wetland ecohydrology can be used to measure accurately the responses of wetland ecosystems to anthropogenic forcings, and provide scientific strategies for their restoration and protection. In this paper, wetland ecohydrology of a given region is conceptualized as comprising three spheres: human disturbances, hydrological dynamics and the response of wetland natural ecosystems. A geoinformatic framework is applied for the quantitative expressions of the connections, both between and within these spheres. With wetland ecohydrology representing a systematic and integrative methodology in contrast to narrow, disciplinary approaches, we focus on the issue of balancing limited water resources between natural wetland ecosystems and human activities, and in particular the scientific approach on how to estimate the proportion of natural wetland ecosystems to preserve in agricultural areas in order to ensure sustainability. In doing so, we aim to facilitate the development of a harmonious relationship between natural wetland ecosystems and local communities and thus the promotion of sustainable regional development.

1. Ecohydrology conception and its theories in wetland science

Ecohydrology has developed into an extensive and recognized field in less than two decades. Zalewski, the first scientist to define ecohydrology in 1996 (Zalewski et al., 1997), noted that, "understanding of the functional inter-relations between hydrology and biota at the catchment scale, is fundamental for controlling and restoring ecological processes that will enhance the resistance and resilience of an ecosystem" (Zalewski et al., 2009). Many researchers have put forward definitions of ecohydrology (Acreman, 2001; Rodriguez-Iturbe, 2000; Porporato et al., 2002), with the interactions between ecologic patterns and hydrological mechanisms generally the key component. For example, Rodriguez-Iturbe (2000) views ecohydrology as the science that seeks to describe the hydrological mechanisms underlying ecologic patterns and processes.

One of the central scientific concerns in ecohydrology is to quantify the interactions between plants and the water in their habitats through analysis of spatial patterns and temporal processes (Wood et al., 2008). A primary focus is

* Corresponding author at: College of Resource, Environment and Tourism, Capital Normal University, Beijing 100048, China.
Tel.: +86 010 6898 0798; fax: +86 010 6890 3030.
E-mail address: zhoudemin@neigae.ac.cn (D. Zhou).

http://dx.doi.org/10.1016/j.ecohyd.2015.08.004
1642-3593/

the characteristics of the availability of water in the habitat and its transfer in spatial and temporal dimensions. It concerns also the functional characteristics of water apparent in its influences on regional ecosystems – the basic element of the biotic environment for wildlife habitats (Ghimire and Johnston, 2013). An additional focus is related to how water-dependent ecosystems respond to hydrological processes, and in turn influence water presence and its spatial and temporal variations. During these interactive processes, water in soil is a key factor connecting climate change and plant ecological dynamics at different spatial and temporal scales. Thus, plants are at the core of ecohydrology (Rodriguez-Iturbe, 2000; Zalewski et al., 2009).

As a sub-discipline of ecohydrology, wetland ecohydrology is the science focusing on the links and coupling mechanisms between plant ecology and habitat water in wetlands. Wetlands therefore are the interface between land and water. On the one hand, as the basic element of hydrology, "wet" is one of the fundamental properties of wetlands, and through water movement serves as a natural carrier; on the other hand, biodiversity is the basic element of ecology and, especially because wetland ecosystems have the highest biodiversity value on Earth, wetlands are bound to be one of the highest concerns for ecologists in their studies (Mitsch, 2007). Wetlands function through strong interactions between hydrology and ecology, and thus are central environments for ecohydrological research, including the development of the core theories of ecohydrology and the associated methodology.

2. The anthropogenic era and its challenges to the natural ecosystem

Since the middle of the last century, rapid progress in science and engineering has resulted in great improvements in productivity and global living standards. However, in doing so, human activities have produced extensive and rapid perturbations of natural ecosystems, resulting in what is now recognized as the "anthropogenic era". In particular, development has come through squeezing the physical spaces of various natural ecosystems, for example through land use and land cover change such as that caused by mass urbanization, and the associated direct or indirect accelerated rapid destruction of biotic habitats (Luan and Zhou, 2013). In addition, natural ecosystems face challenges through global climate change induced by human activities that have a long-term and irreversible negative impact on the living environment for natural ecosystems.

With sustained rapid development over the past half century across the world, the world's most pristine natural wetlands are disappearing quickly. Since the productivity of developing countries was not high in the past, their capacity to reclaim natural wetlands was limited. Therefore, before the end of the last century, developing countries in Africa, South and Central America, and Southeast Asia had high proportions of the then remaining original wetlands of the world. However, with the rising economies of "the BRIC countries" (Brazil, Russia, India and China) as the main players in the global economic development boom, the destruction of many of the world's original natural wetlands has been increasing rapidly in the past two or three decades and the destruction process now is further evolving.

Wetlands are the most valuable areas for protecting the Earth's biodiversity and yet the wetland ecological environment is also the most vulnerable. Despite massive ecological protection measures carried out by developing countries, the future health and sustainability of many protected natural wetlands remains questionable due to poor implementation of policies and ineffective legislative measures (Luan and Zhou, 2013). Wetland ecohydrology is an effective scientific tool to address such concerns in this anthropogenic era, by measuring the response characteristics of wetlands to anthropogenic stress, and providing scientific strategies with practical value for carrying out wetland restoration and protection. Thus, wetland ecohydrology has attracted widespread attention.

3. Reviews and comments on current wetland ecohydrological methodology

The majority of current ecological problems are triggered directly or indirectly by water issues. However, ecology and hydrology have for a long time been categorized into disciplines of two different natural sciences, even though there are obvious trends of demand for more interdisciplinary research. The development of ecohydrology as an interdisciplinary activity parallels the growth in general interdisciplinary research. But there are still many practical difficulties in linking the individual disciplines' theory systems and methodologies, due to the large gap between the different scientific foundations of the fundamental disciplines of ecology and hydrology. Take ecohydrology of wetlands for instance. The current study of hydrology emphasizes simulating the rainfall and runoff processes while giving less attention to ecological factors, especially the ecological landscape features (Uhlenbrook, 2006); at the same time, currently ecologists focus on the ecosystem structures, functions and processes, as well as the characteristics of ecological patterns and scales while generally lacking in-depth understanding of hydrological processes and mechanisms. Currently wetland ecohydrology study also lacks a precise understanding of connections between ecology and hydrology in wetlands. However, the ecohydrological connection points are critical for scientists to determine the essential principles of wetland-science and basic mechanisms of wetland evolution (Toner and Keddy, 1997; Wheeler, 2000).

Globally, the division of disciplines limits the capacity to respond to global and regional water security issues linked with ecological crises due to bottlenecks constraining the development of sustainable strategies for regional water resources. Although interdisciplinary trends have emerged, the current scientific theories and the corresponding methodology of ecohydrology are still not well established, especially in that advanced technology has yet to be combined with ecohydrological interdisciplinary and coupling theories (Zhou et al., 2010; Zalewski, 2014). In addition, there remain significant methodological difficulties that constrain the development of effective geographical spatial–temporal models due to the unresolved question of how to deal with scale and other essential