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Ecological and hydrological responses to changing environmental conditions in China's river basins

1. Introduction

In the past decades, synergy of human disturbances (e.g., urbanization, deforestation, and hydropower exploitation) and climate change has caused a series of impacts on many hydrological processes in multi-scale river basins, leading to many changes in the environment (DeFries and Eshleman, 2004; Wilcox, 2010; Mitsch, 2012). Such changing environmental conditions are resulting in: (a) the gradual shifts of many water-related processes, parameters and factors (e.g., water cycles, precipitation patterns, and runoff regimes), and (b) the increasing frequencies and intensities of extreme climatic events (e.g., floods and droughts). Either influence pathway of changing environmental conditions may have direct and/or indirect effects on human society and indigenous ecosystems, which in turn have adaptive responses at multiple spatial and temporal scales. At the same time, many water-related and ecological problems are triggered, such as water shortage, habitat fragmentation, and ecological degradation. These problems may cause great losses in lives and properties, and many unrecoverable ecological results (IPCC, 2007).

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Particularly, this is of great urgency in China. In this country, the total length of rivers is over 430,000 km. The number of rivers with over 1000 and 10,000 km^2 individual drainage area is more than 1500 and 79, respectively (MWR, 2012). For example, the total drainage area of China top seven river basins (i.e., basins of Yangtze River, Yellow River, Haihe River, Pearl River, Huaihe River, Songhua River and Taihu Lake) is approximately 1.8×10^6 km^2, accounting for over 20% of its total land area. In the past three decades, due to the adoption of the well-know “Reform and Opening-Up” policy, China has been experiencing unprecedented urbanization and industrialization processes. No country in the history has ever been under such an expedite transition and has profound impacts on both of the social and natural environments. The transition has also led to the consumptions of a huge amount of resources including land and water. Such activities are occurring in every river basin of this country even the far remote ones. A cascade of human disturbances has thus been put upon most of the river basins. Nobody can clearly anticipate possible results of these great changes. Moreover, the disturbances are further multiplied by climate change. Under the combined impacts of climate change and human disturbances, China is facing serious challenges in each individual river basin, such as: (a) increasing frequencies of extreme events, (b) intensive conflicts over water resources between human and ecosystems, (c) rising water pollution, (d) continuous degradation of aquatic and offshore ecosystems, and (e) tradeoff analysis of limited water resources for human beings and ecosystems.

All of these challenges are calling for concentrated research upon inherent mechanisms, process modeling and restoration strategies and technologies, providing a systematic prospective in analyzing effects of human disturbances and climate change on hydrological processes and ecosystems, as well as their responses, it is thus desired that in-depth research efforts be undertaken and effective methodologies be developed. Thus, the purpose of this special issue is to report some of the latest research related to the evolving area, which addresses various issues of ecological and hydrological responses under changing environmental conditions. Given the multidisciplinary and collaborative nature of inquiries into the interaction between ecological and hydrological characteristics and changing environment, the contributions incorporated diversified and creative applications of theories and methodologies from multiple fields, including (a) exploitation of inherent mechanism of ecosystems and environmental changes, (b) modeling and analysis of detailed responding patters and relationships, and (c) identification and evaluation of eco-restoration strategies for reducing potential damages and risks.

2. Special issue papers

After the initial invitation, all selected eighteen papers underwent a thorough peer review process, with at least two rounds of reviews. Following the journal guidelines and requirements, all submitted papers were refereed by at least three well-known experts in the field. These papers contributed in different aspects to the topic of “Ecological and hydrological responses to changing environmental conditions in China river basins”, providing a deeper understanding of relevant issues and presenting novel approaches, techniques and applications for dealing with these issues. The papers can be categorized into three groups, including (a) studies upon relationships between ecological/ hydrological factors and external changes, (b) modeling of detailed ecological/hydrological response under changing environmental conditions, and (c) identification of desired eco-restoration strategies for reducing damages and risks.

2.1. Relationships between ecological/hydrological factors and external changes

There are six papers in this sub-topic, including those contributed by many prestigious researchers in China, including Dr. Rusong Wang, a Chinese Academician of the Chinese Academy of Engineering. In the work of Gao et al. (2015a), the response of fish communities to environmental changes was analyzed in an agriculturally dominated watershed (i.e., Liao River Basin) in northeastern China. Through testing the samples from 187 sites and using univariate and multivariate methods, it was found that 56 species were identified in the basin. The predominant orders were Cypriniformes (33 species) and Perciformes (10 species). Species richness degraded seriously (from 106 to 56 species) compared with the data obtained in the 1980s. Based on the similarity of fish communities, the sampling sites were divided into three groups. Group 1 was distributed in the Hun-Tai River Basin located in the southeast region with less anthropogenic disturbance, and was characterized by high quality of physical habitats and water resources. The other two groups were mainly distributed in the main stem and its tributaries, with many stresses (e.g., high conductivity, COD_{Mn}, and NH_4^+) caused by agricultural and industrial activities. Species richness increased along a longitudinal gradient and reached the maximum in Group 2. The distribution pattern of fish communities was analogue with the scheme of the Grade I aquatic eco-functional zonings and can be used as a good indicator with high verification ability. The indicator species of Group 1 were all small-sized and sensitive to environmental stresses. The results also indicated that physical habitat features (such as velocity, habitat score, cobble plus boulder, and dissolved oxygen) and chemical pollutants (such as NH_4^+, COD_{Mn}, conductivity, and TN) structured the fish communities in the river.

Zhou et al. (2015) analyzed the effects of human activities on the eco-environment in the middle Heihe River Basin based on an extended environmental Kuznets curve model. Through employing and analyzing data on land use, surface and ground water, climate, gross domestic product (GDP) per capita from the middle Heihe River Basin, changes were identified and evaluated for water consumptions, land use composition, and vegetation cover. Also, the effectiveness of short-term management strategies was evaluated for environmental protection and improvement. Besides, an environmental Kuznets curve (EKC) based framework was applied and extended to describe the relationship between economic development and environmental quality in terms of the normalized difference vegetation index (NDVI). The results showed that with rapid development of agriculture and economy, land use change for the period 1986–2000 was characterized by the expansion of constructed oases, as well as the considerable contraction of oasis-desert transitional zones and natural oases. This has led to a decrease in ecosystem stability. Since 2001, effective basin management has brought about improved environment conditions, with a more optimal hierarchical structure of vegetation covers. The original EKC model could not explain the majority of the observed variation in NDVI ($R^2 = 0.37$). Including additional climatic variables, the extended EKC model to explain the observed NDVI was much enhanced ($R^2 = 0.78$), suggesting that inclusion of biophysical factors should be a necessary additional dimension for analyzing the relationship between economic development and environmental quality for arid regions with great climate variability. Comparatively, the relationship between GDP per capita and NDVI, with the effects of precipitation and temperature taken into consideration, was adequately described by an N-shaped curve.

Wang et al. (2015b) investigated temporal–spatial precipitation variations during the crop growth period in Lancang River Basin,