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Preface

"Practice and strategies for managing water conflicts between human and ecosystems"

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1 Introduction

Water conflicts between humans and ecosystems are key issues for sustainable water resource management. In the past decades, human-oriented regulation of water resources and construction of many hydraulic projects for hydropower generation, agricultural irrigation, and flood control has significantly altered natural flows in many rivers, resulting in increasing variances in water availabilities and flow regimes. For example, every year, a large amount of water is being diverted for agricultural irrigation in major river basins worldwide. Annually, over 70 % of water is extracted from the rivers to meet agricultural water needs in many countries. Particularly, a number of rivers are subjected to extremely high water extraction rates and the water can hardly reach the sea. Incessant declination in water availabilities has caused a series of impacts on many valuable aquatic habitats, such as riparian floodplains, wetlands, and estuaries. Due to population growth and economic development, enhanced amounts of freshwater are expected to be extracted to support human activities, further worsening such situations.

Conflicts over water resources are thus intensive for human beings and ecosystems across the world. Many concerns are rising, particularly in many developing countries. For example, in China, since the early 1970s, the frequency of drying or ephemeral stream flows has been increasing in the Yellow River, which is the sixth largest river in the world. Since the early 1990s, drying took place annually in this river. Averagely, the time length without water in the lower reach of the river was approximately 100 days every year. Such extreme alterations have caused a cascade of adverse impacts on hydrological diversity, species distribution, and indigenous ecosystems in the Yellow River basin. This may eventually lead to unrecoverable effects on biodiversities, services, and even core functions of the associated ecosystems. Similarly, the other major river of China, i.e., the Yangtze River, is also subject to great alterations due to the construction of many mega water-related projects, such as the Three Gorges Dam and the South–North Water Transfer Project. Considering the pressure of stimulating economic growth in many developing countries across the world, similar constructions and projects have been undertaken. However, due to complexities of the associated river systems, as well as the interactions between humans and ecosystems, no clear results could be obtained regarding what unrecoverable and/or recoverable effects would happen because of such profound alterations. Moreover, the alterations may be multiplied by climate change, further affecting water availability and thus intensifying water competition between humans and ecosystems. In order to achieve sustainable water resource management, fostering a socio-economically and ecologically healthy consensus over water demands by humans and ecosystems is of great importance. Environmental flow that can be used to quantify the amount of water needed by a given ecosystem has become a competitive component with human water demand in watershed management. Thus, the management of water conflicts between humans and ecosystems in river basins is desired.

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2 Special Issue Papers

There are totally 13 papers in this special issue, including those contributed by many prestigious researchers. Following the journal guidelines and requirements, all submitted papers were refereed by well-known experts in the field. These papers represented an achievement to studies on hydrological and ecological sciences and engineering, and can provide scientific bases for sustainable water resource management. In the work of Feng et al. (2014), the growth of total dissolved gas (TDG) resulted in an increased incidence of gas bubble disease of fish in the Bala Reservoir over the Zumuzu River. It has been proved that supersaturated TDG was transported and dissipated more slowly in reservoirs than in natural rivers because of a higher water depth and lower turbulence. In their paper, the joint operation of the upstream and downstream power stations was studied based on a laterally averaged two-dimensional model through which the TDG transportation and dissipation, as well as the hydrodynamics and water temperature in the Bala Reservoir were simulated. According to a comparison of the simulated results under multiple operational scenarios, results of this paper suggested a number of regulation schemes. With respect to the upstream power stations, the adoption of an interval-discharge pattern instead of a continuous-discharge pattern was recommended to minimize the negative effects on the reservoirs caused by supersaturated TDG. With respect to the downstream power stations, the adoption of a surface tunnel rather than a bottom one was recommended as a water release pattern. Results of their paper provided a reference for the eco-environmentally friendly operation of large and deep reservoirs.

Pang et al. (2014) proposed an approach for supporting environmental flow decision making based on Bayesian networks considering seasonal water use conflicts between agricultural activities and ecosystems. Three steps were included in the approach: (a) water shortage assessment after environmental flow allocation using a production-loss model considering temporal variations of river flows, (b) trade-off analysis of water use outcomes through Bayesian networks, and (c) environmental flow decision making based on risk assessment under different management strategies. Agricultural water shortage and production-loss models were integrated after satisfying environmental flows with temporal variability. The case study in the Yellow River estuary indicated that the average difference of acceptable economic losses for winter wheat irrigation stakeholders was 10 % between water saving measures and water diversion projects. The combination of water diversion projects and water-saving measures would allow 4.1 % more river inflow to be allocated to ecological needs over normal hydrological years without causing further economic losses in agriculture.

Chen et al. (2014) established a MAP-PMA (Multiple-Assessment-Point-Priority Management Area) framework through integrating the upstream source and the downstream transport aspects of NPS (Non-Point Source) pollution. Based on the results, the integration of the upstream input changes was vital for the final PMA map, especially for the downstream areas. Contrary to conventional measures, this research recommended that the NPS pollutants could be best controlled among the upstream high-level PMAs when protecting the water quality of the entire watershed. The proposed MAP-PMA framework provided a cost-effective tool for the establishment of conservation practices, especially for a large-scale watershed.

Zhi et al. (2014) proposed a framework in which input–output (IO), structural decomposition analysis (SDA) and generating regional IO table (GRIT) methods were combined to implement decomposition analysis for water footprints (WF) in a river basin. The developed framework was illustrated through the calculation of WFs in Haihe River basin (HRB) over 2002 to 2007, a water-stressed river basin in northern China. The results indicated that the total WF in the HRB increased from 4.3×10^{10} m^3 in 2002 to 5.6×10^{10} m^3 in 2007. Over the study period, agriculture sector made the dominant contribution to WF growth. Both WFs of domestic products (i.e., internal WF) and WFs of imported products (i.e., external WF) increased. Correspondingly, the proportion of external WF rose from 29.1 to 34.4 % over the studying period. The technological effect was the dominant contributor to offset WF growth. However, the growth of WF caused by effects of economic structure and economy of scale was greater than that of technological effects. Thus, the total WF increased significantly. This research provided insights into water challenges in HRB. Possible development strategies were identified and advanced, and would serve as references for WF management and policy-making in similar water-stressed river basins.

T. Zhang et al. (2014) investigated temporal and spatial changes in the water quality of Dianchi Lake, southwestern China, by collecting monthly data for 2005 to 2012. Dianchi Lake was divided into two sub-lakes (i.e., the Caohai and Waihai lakes) by a man-made dike. Among them, Waihai Lake is the primary water body of Dianchi Lake, and accounts for 96.7 % of the entire area of the lake. Based on the analysis of total phosphorus (TP), total nitrogen (TN), and chlorophyll *a* (Chl *a*) concentrations, it was determined that, in Caohai Lake, the annual concentrations of these variables ranged from 0.19 to 1.46, 6.11 to 16.79, and 0.06 to 0.14 mg L^{-1}, respectively. In addition, the annual concentrations of TP, TN and Chl *a* in Waihai Lake ranged between 0.13 and 0.20 mg L^{-1}, 1.82 and 3.01 mg L^{-1}, and 0.04 and 0.09 mg L^{-1}, respectively. Through adopting cluster analysis (CA) method, the 10 monitoring sites were categorized into two clusters (i.e., clusters A and B) based on similarities/differences in water quality features. The results indicated that the current status of the water quality within Caohai Lake was much worse than that of Waihai Lake. Water quality was seriously degraded during the economic boom over the period of the “the Eleventh Five-Year Plan” (i.e., 2005 to 2010), and gradually improved from 2010 to 2012.

The fundamental improvements of the water quality within Caohai Lake was dependent on the measures taken in the upper reaches of the Caohai Watershed, such as recovery of submerged plants, floating plant utilization, and sediment disposal. Management strategies for endogenous pollution in Waihai Lake were mainly dependent on restocking algae-eating fish and the ecological restoration of macrophytes. Such management strategies would be further adopted for supporting water conflict management between mankind and ecosystems in similar lakes across China.

Yin et al. (2013) established a framework to determine the optimal portfolio for a hydropower reservoir, which could balance economic benefits and ecological needs. In this framework, the degree of natural flow regime alteration was adopted as a constraint to hydropower generation for protecting riverine ecosystems. Maximization of the mean annual revenue was set as the objective function of the optimization model. The electricity volumes assigned in different electricity submarkets could be optimized through the adoption of the noisy genetic algorithm. The proposed framework was applied to China's Wangkuai Reservoir to demonstrate its applicability. The results showed that the developed framework could help design eco-friendly portfolios that would ensure a planned profit and reduce alteration to natural flow regimes in rivers.

Dong et al. (2013) developed a dual inexact fuzzy stochastic programming (DIFSP) method for supporting the planning of water and farmland management systems considering non-point source (NPS) pollution mitigation under uncertainty. The random boundary interval (RBI) was incorporated into DIFSP through integrating fuzzy linear programming (FLP) and chance-constrained programming (CCP) approaches into an interval linear programming (ILP) framework. This developed method could effectively tackle uncertainties expressed as intervals and fuzzy sets. Moreover, the lower and upper bounds of RBI were continuous random variables, and the correlation existing between the lower and upper bounds could be tackled in RBI through the joint probability distribution function. The proposed method was then applied to solve a water and farmland use planning model (WFUPM) with the consideration of NPS pollution mitigation. The generated results could provide decision makers with detailed water supply–demand schemes involving diversified water-related activities under preferred satisfaction degrees. These useful solutions could allow in-depth analyses of the trade-offs between humans and environment, as well as those between system optimality and reliability. In addition, comparative analyses on the solutions obtained from ICCP (interval chance-constraints programming) and DIFSP demonstrated the higher applicability of this developed approach for supporting the water and farmland systems planning.

Zhao et al. (2014) established a zoning-based environmental–ecological coupled model for a lake. Hierarchical cluster analysis was adopted to determine the number of zones in a given lake based on hydrological, water quality, and ecological data analyses. The MIKE 21 model was used to construct two-dimensional hydrodynamics and water quality simulation models. Also, STELLA software was used to create a coupled lake ecological model that could simulate the spatial variations of ecological conditions based on flow field distribution results generated by MIKE 21. The proposed model was then applied to Baiyangdian Lake. The results showed that the proposed model was promising for predicting spatial variations of ecological conditions in response to changes in lake water quantity and quality, and was useful for supporting lake management.

Liu et al. (2014) developed a fuzzy multi-attribute decision analysis approach (FMADAA) to support the evaluation of water resource security in nine provinces within the Yellow River basin. A numerical approximation system and a modified left–right scoring approach were adopted to cope with uncertainties in the acquired information. Also, four conventional multi-attribute decision analysis (MADA) methods were implemented in the evaluation model for impact evaluation, including simple weighted addition (SWA), weighted product (WP), cooperative game theory (CGT) and techniques for order preference by similarity to ideal solution (TOPSIS). Moreover, several aggregation methods including average ranking procedure, Borda and Copeland methods were used to integrate the ranking results, helping rank the water resource security in those provinces as well as improving the reliability of the evaluation results. The results showed that the water resource security of the entire basin was in a critical condition, including the insecurity and absolute insecurity states, especially in Shanxi, Inner Mongolia and Ningxia provinces, in which water resources were lower than the average quantity in China. Hence, the improvement of water eco-environment statuses in the above-mentioned provinces should be prioritized in the future planning of the Yellow River basin.

Xu et al. (2014) proposed a approach to optimize the initial planting area and monthly harvest schemes of macrophytes for water quality improvement. The month-by-month effects of macrophyte management on lake water quality were considered. Baiyangdian Lake was served as a case study. It was found that water quality in this lake was slightly lower than Grade III based on the Chinese water quality scale when the reed planting area was 123 km^2 (40 % of the lake surface area), and most reeds would be harvested at the end of June. The optimization approach proposed and the generated results in this study could be a useful reference for lake restoration across China for managing water conflicts between ecosystems and human activities.

Yang et al. (2014) developed an approach to assess estuarine environmental flow based on phytoplankton preferences. A relationship between biomass requirements for primary and higher nutritional level organisms was established initially. Then, diagnostic pigments were employed to represent phytoplankton community biomass, which indicated competition between two groups of phytoplankton in the biochemistrical process. Considering empirical relationships between diagnostic pigments and critical environmental factors, biomass responses to river discharge were established by simulating distributions of critical environmental factors under actions of river discharges and tide currents. The proposed approach was then applied to the Yellow River estuary, and May and June were identified as critical months for maintaining environmental flows.

Hurford et al. (2014) proposed an approach to identify and help decision makers visualize reservoir management strategies as well as to show how trade-offs between achievable benefits shift with the implementation of proposed new rice, cotton and biofuel irrigation projects. A water resource management simulation model was linked to a multi-criteria search algorithm so as to approximate the Pareto-optimal trade-offs. Results quantified how economic gains from proposed irrigation schemes trade-off against the disturbance of ecosystems and local livelihoods that depend on them. Full implementation of the proposed schemes was shown to come at a high environmental and social cost. The clarity and comprehensiveness of a best-case trade-off analysis was a useful vantage point from which to tackle the interdependence and complexity of water-energy–food nexus resource security issues.

L. J. Zhang et al. (2014) took the virtual water content (VWC) of rice as their research subject. The VWC of rice in China was assessed and the spatial characteristics were also analyzed. The total VWC was the total volume of freshwater both consumed and affected by pollution during the crop production process, including both direct and indirect water consumptions. Prior calculation frameworks of the VWC of crops did not contain all of the virtual water content of crops. In addition to the calculation of green, blue and grey water – the direct water in VWC – the indirect water use of rice was also calculated, using an input–output model. The percentages of direct green, blue, grey and indirect water in the total VWC of rice in China were found to be 43.8, 28.2, 27.6, and 0.4 %, respectively. The total VWC of rice generally showed a roughly three-tiered distribution, and decreased from southeast to northwest. The higher values of direct green water usage were mainly concentrated in southeastern and southwestern China, while the values were relatively low in northwestern China and Inner Mongolia. High direct blue water values were mainly concentrated in the eastern and southern coastal regions and northwestern China, and low values were mainly concentrated in southwestern China. Grey water values were relatively high in Shanxi and Guangxi provinces and low in northeastern and northwestern China. The regions with high values for indirect water were randomly distributed, but the regions with low values were mainly concentrated in northwestern and southwestern China. For the regions with relatively high total VWC the high values of blue water made the largest contribution, although for the country as a whole the direct green water is the most important contributor.

3 Conclusions

Conflicts over fresh water are of increasing concern between human beings and ecosystems across the world. Due to increasingly intensive disturbances by human beings in many river basins, great potential damages and risks are believed to be associated with indigenous ecosystems. A cascade of adverse impacts on water quality and quantity, river regime and hydraulic features has occurred, leading to many effects upon ecosystems. Managing conflicts over water resources between human beings and ecosystems are thus of great significance in many watersheds across the worlds. Many efforts have been adopted for dealing such a challenge by research and governmental communities. Theoretical investigation, process modeling, and strategy evaluation and identification have been undertaken and were the main topics of the papers in this special issue. Such a batch of achievements would present a scientific foundation not only for researchers, but also for decision makers for many rivers, wetlands and reservoirs.

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