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Harmoniousness analysis of total amount control of water use

Qian-qi YIN*, Guo-hua FANG

College of Water Conservancy and Hydropower Engineering, Hohai University, Nanjing 210098, P. R. China

Abstract: Based on the fundamental principles of total amount control of water use, the harmony theory was used in this study to develop a concept of the degree of harmony of total amount control of water use. Based on this concept, the harmoniousness of total amount control of water use was analyzed in terms of the supply and demand of water resources, water resources management, water use benefits, and water-saving level. An evaluation index system of the degree of harmony of total amount control of water use was established, and a method for calculation of the degree of harmony of total amount control of water use was developed based on the analytic hierarchy process (AHP) and fuzzy comprehensive analysis (FCA) methods. The new evaluation index system was applied to a certain area in Jiangsu Province, China. The degree of harmony of total amount control of water use over this area was calculated for different years. Results indicate that the evaluation index system and calculation method proposed in this study are feasible, and such a harmoniousness analysis can provide scientific references for the strict water resources management system that will be implemented in China in the near future.

Key words: *total amount control of water use; degree of harmony; evaluation index system; quantification method; analytic hierarchy process method; fuzzy comprehensive analysis method*

1 Introduction

Water resources are widely regarded as the most essential natural assets for humans, wildlife, and ecosystems. Most people believe that shortage of water resources will be the primary factor constraining economic and social sustainable development in the 21st century. In 2011, the Central Committee of the Communist Party of China and the State Council released their decision on *Acceleration of Water Conservancy Reform and Development*, which formally claimed that a strict water resources management system would be established in the next five years. Then, the Ministry of Water Resources of China established the *Red Line* implementation scheme for the future utilization of water resources so as to strictly control the total amount of water use. Studies on total amount control of water use have mainly focused on control methods, statistical indices, and the development of evaluation systems. Ren (2005) comprehensively analyzed the relationship between the total amount control of water use and quota management, suggesting that their combination is rather

*Corresponding author (e-mail: *hhu_yinqianqi@126.com*)
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necessary in practice. Cao (2007) compared various control methods for water use across the Taihu Basin. Lin and Zou (2010) discussed the statistical indices and the evaluation system of total amount control of water use in detail. Zeng et al. (2011) adopted several control indices to investigate the total amount of water use for the main channel and branches of the Yangtze River. Li et al. (2012) analyzed the variation trends of the total amount of water use, water consumption of industrial departments, and water use efficiency within the Yangtze River Basin and its second-grade zone of water resources since the 1980s, and then proposed a set of control indices of the total water use for the Yangtze River Basin. Wang et al. (2012) comprehensively analyzed and discussed the principles, baselines, methods, and technical processes for determining the control index of total water use. However, few researchers have considered the time continuity, the spatial equilibrium, and the system coordination for the total amount control of water use, and few have proposed a level that the total amount control of water use should reach, reflecting the strict water resources management criteria.

As a comprehensive multi-dimensional description of the operational state of a system at a certain time, the degree of harmony has been widely used in large-scale water resources systems. Wang et al. (2003) proposed the concept of the degree of harmony of water resources allocation and developed an evaluation index system to quantitatively analyze the harmoniousness of water resources allocation. Aiming at the optimal use of limited water resources, Chang et al. (2004) employed a harmony index as a feedback regulator to adjust the simulation results, which can provide the theoretical and technical support for sustainable development of water resources in the Yellow River Basin. Wang et al. (2007) used the analytic hierarchy process (AHP) method to evaluate the degree of harmony of water resources allocation. Li et al. (2007) discussed the harmoniousness level and the principle of a complicated micro-system of water resources. Taking Zhengzhou City as an example, Zuo et al. (2008) established a quantitative index system for human-water harmony and developed a method for calculating the degree of harmony. Shen et al. (2008) developed a model of the degree of harmony for the settlement system in terms of the social system, economic system, environmental system, and resource system, and the model was applied in the Santongbao Project of the South-to-North Water Diversion Project. Zuo (2009) proposed five elements of the harmony theory and a degree of harmony equation from the view of mathematics, which was used in water allocation in the Yellow River Basin. Ma and Zheng (2011) used the normal-efficiency data envelopment analysis (NEDEA) and super-efficiency data envelopment analysis (SEDEA) models to calculate the degree of harmony between water resources and economic development of Beijing City. Results show that the SEDEA model is suitable for local regional water resources management. Hou et al. (2011) constructed a mathematical model for evaluating the degree of harmony of water resources utilization, and this model was used to quantitatively analyze the degree of harmony of water resources utilization in the Bortala Mongol Autonomous Prefecture. Deng et al. (2012) set up an evaluation system for the

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