Assessing water security and adaptation measures in a changing environment

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Increasing water shortage is a major concern across the world as it has posed serious threats to food security and economic development in many parts of the globe (Butler and Memon 2006, Wang *et al.* 2012). The situation is set to become worse in the coming decades due to population growth, economic development, urbanization and climate change. Ensuring water security will be a great challenge and, therefore, more justifiable practices in water resources management are necessary to adapt with environmental changes (Wang *et al.* 2011). Many indices have been developed to evaluate water security using various types of assessment models. However, progress achieved in the systematic application of indicator-based assessment methods or the translation of the results into water resources management strategies, is still little. It is required to assess water security in an evocative way so that it can provide adaptation policy options to mitigate the global change impacts on water security (Zhang 2005, Wang *et al.* 2011, 2014a).

The existing models generally evaluate water security using the perception of decision makers of the influence of different water security indicators, which often causes bias in evaluation and adaptation measures. Catastrophe theory has the capability to evaluate the importance of one criterion over other without involving human perception in decision making. Therefore, it can greatly reduce the subjectivity in human perception and, thus, help in identifying the water management strategy to achieve water security under changing environment more reliably (Wang *et al.* 2014b). A catastrophe theory based multi-criteria evaluation system is proposed in this study for the assessment of the water security of Yulin city, in Northwest China, under different water management scenarios in the context of climate change, population growth and economic development, in order to identify the best water management strategy to adapt with the changing environment. In the proposed method, water security is considered as a system with five sub-systems, namely: water resources security, water-society security, water-economic security, water-environment security and external environment security. Sixteen indicators of five water security sub-systems, namely GDP, urbanization, temperature, water shortage, surface water supply ratio, other water sources supply ratio, per capital water resources, Gini coefficient of domestic water use, per capita domestic water consumption, irrigation water quota, water consumption per unit industrial production, economic elasticity of water use, water price, pollution−dilution ratio, water resource utilization and water consumption rate, were selected for modelling water security, show as Fig. 1. Each indicator of a sub-system is initially assigned with observed or simulated data and then normalized by using the corresponding catastrophe model to get the fuzzy membership function of the corresponding sub-system. The fuzzy membership functions are then used for the evaluation of water security of Yulin city under three potential water resources management strategies: business-as-usual, water supply management and water demand management. Data for projected climate, water resources, land use and various socio-economic indicators were collected from the planning reports of Yulin city and used in the present study.

The results show that water shortage in Yulin city will be stabilized if a water demand management strategy is adopted. However, by 2030 it will increase by up to 70% and 41% under the business-as-usual and water supply management strategies, respectively. Huge increases of water supply as required under the business-as-usual and water supply management strategies are

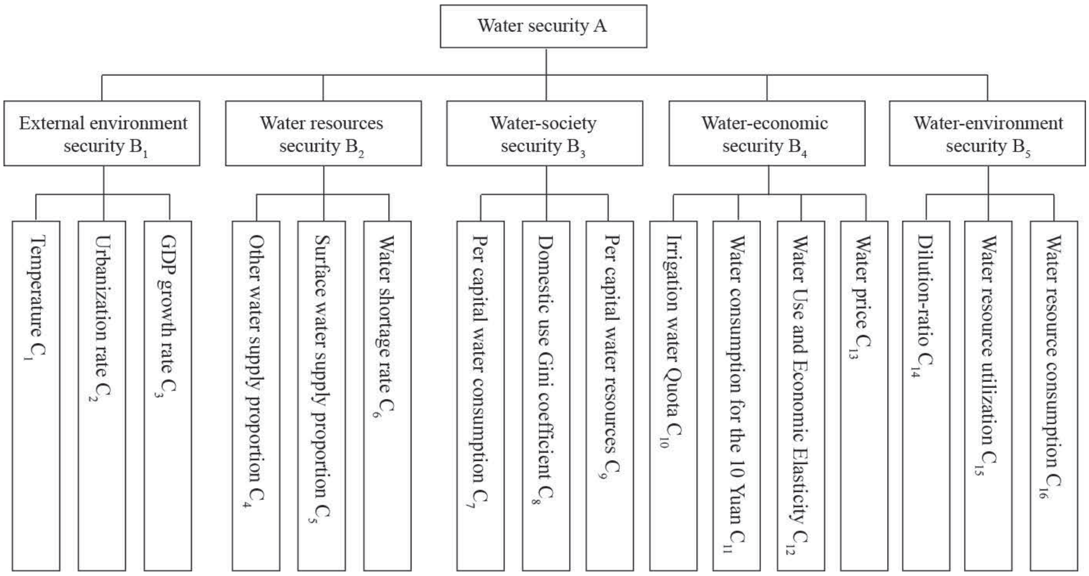

Fig. 1 Indicator system of water security assessment model under changing environment.

impossible as they may cause a threat to the ecological environment and significant levels of water pollution (Wang *et al*. 2009, 2010). But, strict water demand management strategies are more likely to affect the rate of economic growth. Water demand management alone will also not able to mitigate water scarcity of the city as the amount of water shortage will still be 5.16×10^8 m^3 in 2030. Therefore, supplementation of the water supply through water diversion from the Yellow River will still be required. The study suggests that a combination of water supply and demand management strategies is required for sustainability in water resources; however, more emphasis should be given to water demand management.

The methodology developed in the present study can be an effective tool for measuring water scarcity and adopting appropriate water management strategy in the context of global environmental changes. It can be used in other regions using a set of indicators appropriate for the region.

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