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Risk assessment of water resources shortage in consideration of urbanization trends in Guangdong Province, China

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Abstract. To improve the application of conventional methodology on water resources shortage for region development in risky conditions, an integrated approach was developed, coupled with data uncertainty analysis, and violation risk analysis methods. The methodology can effectively connect uncertain equilibrium between water supply and demand in consideration of urbanization trends. Concretely, the methodology can (a) reflect and address uncertain features of water demands, (b) assess risks of water resources shortage. The developed method was verified in Guangdong Province of China. The application indicated that the proposed method was effective in risk assessment of water resources shortage.

Introduction

Managing water resources under conditions of uncertainty and scarcity is becoming a daily business in many catchments and regions worldwide[1]. Previously, a number of approaches were developed for uncertainty analysis for water resources management[2]. Data quality assessment and Monte Carlo simulation (MCS) were widely used in many studies (e.g., Wang and Shen[3]). Meanwhile, water resources shortage (i.e., failure to meet water demands) may be generated by varying water demands in future uncertain urbanization trends. To quantitatively and systematically explore the likelihood of the incident, violation risk analysis should be incorporated[4]. Previously, violation risk seldom linked with water resources management to support decision making in uncertain conditions. Therefore, the objective of this study is to develop a hybrid method for risk analysis of water resources shortage in consideration of urbanization trends. The developed method will then be demonstrated in Guangdong Province of China.

Methods

Uncertainty analysis Uncertainty of water demands of future can be calculated by the data quality assessment (Equation 1).

$$U_0 = \sqrt{\sum_i^6 U_i^2} \quad (1)$$

where, $i \in \{1, 2, \mathbf{K}, 5\}$ is source reliability, U_1 to U_6 are supplier independence, acquisition method, data representativeness, age, geographical correlation, and technological correlation[5]. The data quality is scored by a spectrum matrix[6]. Then, data uncertainty can be estimated by Monte Carlo simulation (MCS) based on transformation matrix (Table 1)[6-8].

Table 1 Transformation matrix

Quality Score	R	Beta distribution function	
		Shape parameters (α, β)	Range endpoints $(\pm r)$
5	$0 \le R$ <12.5%	(5, 5)	10%
4.5	12.5% $\le R$ <25%	(4, 4)	15%
4	25% $\le R$ <37.5%	(3, 3)	20%
3.5	37.5% $\le R$ <50%	(2, 2)	25%
3	50% $\le R$ <62.5%	(1, 1)	30%
2.5	62.5% $\le R$ <75%	(1, 1)	35%
2	75% $\le R$ <87.5%	(1, 1)	40%
1.5	87.5% $\le R$ <100%	(1, 1)	45%
1	R = 100%	(1, 1)	50%

Risk analysis of water resources shortage The risk of water resources shortage is defined as the occurrence probability of the event, which the demand of water resources exceed water supply capacity of future (Equation 2)[9]. Assuming violation risks [i.e., $H \ge (1-a)H_{2005}$] can be stated by simulating the random variables through Monte Carlo sampling (MCS) as Equation 3[10]:

$$R = P[D > S] = \frac{1}{N}\sum_{j=1}^{N} I(D) \quad (2a)$$

$$I(D) = \begin{cases} 1, \ if \ D \ge S \\ 0, \ if \ D < S \end{cases} \quad (2b)$$

where R is risk of water resources shortage in future urbanization trends, D is water demand in future, S is water supply capacity, N is the total number of MCS conducted and $I(D)$ is an indicator for failure.

Case study

Guangdong Province, one of China's major economic contributors, is faced with increasing water demands due to rapid economic development and a surging population. According to water resources bulletin of Guangdong Province, total water supply was 44.25 billion m^3 in 2015. The main water source of the province was surface water, which contributed 96.2% water resources. In the 13th five-year plan for water resources development of Guangdong Province, water supply capacity of Guangdong Province in 2020 would be 45604 million m^3. The demands of water resources in Guangdong Province in base and planning years are described in Table 2.

Uncertainty and risk analysis In this research, the water demands of multiple stakeholders (e.g., urban and rural residents, agriculture, and industries) are estimated referred to the 13th five-year plan for economic and social development in Guangdong Province. Thus, the DQI and quality score of water demands can be described as (4, 4, 4, 3, 4, 3) and 2.5. Thus, the probability density functions (PDF) of water demands of Guangdong Province in 2020 can be obtained by Monte Carlo simulation (Figure 1). Also, maximal amount of water demand could be much bigger than water supply capacity. Thus, water resources shortage in consideration of urbanization trends in Guangdong Province would be prominent (i.e., more than 30%).

Table 2 The demand of water resources in Guangdong Province

Users		Unit	2015	2020
Urban residents	Population	[10^4 people]	7453.26	8173.80
	Demand per year	[10^8 m^3]	[57.13, 76.17]	[62.65, 83.54]
Rural residents	Population	[10^4 people]	3395.74	3226.20
	Demand per year	[10^8 m^3]	[17.35, 18.59]	[16.49, 17.66]
Agriculture	Demand per year	[10^8 m^3]	227.00	252.80
Industries	Water Consumption per 10000 Yuan of Value-added	[$m^3/10^4$yuan]	37.00	25.90
	Gross Industrial Output Value	[100 million yuan]	24764.87	34734.01
	Demand per year	[10^8 m^3]	112.50	89.96
Total		[10^8 m^3]	434.26	443.96

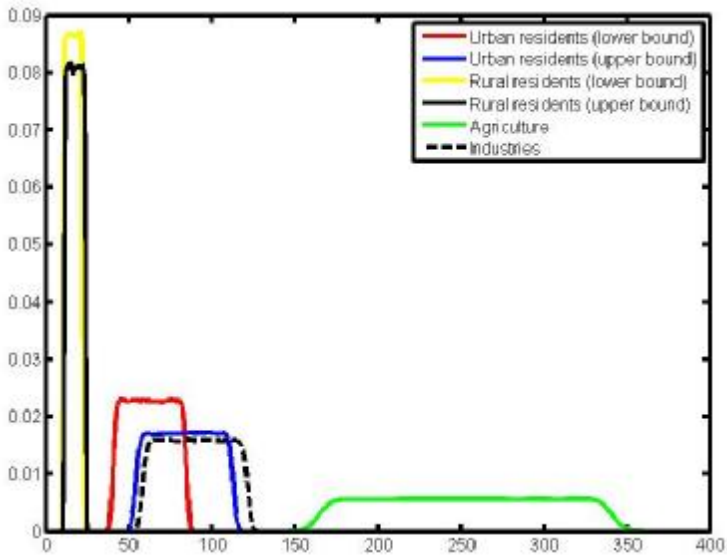

Figure 1 Probability density functions (PDF) of water demands of 2020 in Guangdong Province

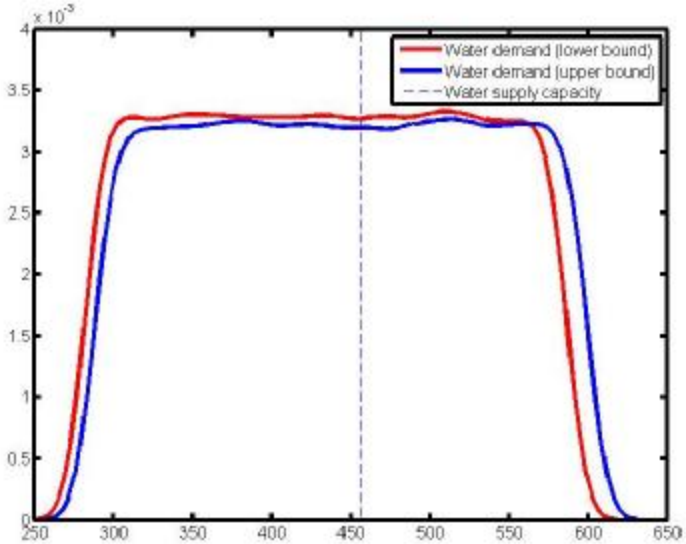

Figure 2 Violation risk of water supply target of 2020 in Guangdong Province

Conclusions

In this research, an integrated approach was developed for risk analysis of water resources shortage in consideration of urbanization trends. Coupled with data uncertainty analysis, and violation risk analysis methods, the methodology can effectively connect uncertain equilibrium between water supply and demand. In detail, the methodology can (a) reflect and address uncertainties of water demand, (b) assess risks of water resources shortage. The developed method was verified in Guangdong Province of China. The application indicated that the proposed method was effective in risk assessment of water resources shortage. It is indicated that water resources shortage in consideration of urbanization trends in Guangdong Province would be prominent.

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References

[1] A. G. Ramos and A. Garrido, *Water Resources Research, 40*. 1 (2004)
[2] I. Maqsood, G. H. Huang, Y. F. Huang and B. Chen, *Stochastic Environmental Research and Risk Assessment 19*, 125 (2005)
[3] E. Wang and Z. Shen, *Journal of Cleaner Production 43*, 166 (2013)
[4] H. Yao, X. Qian, H. Yin, H. Gao and Y. Wang, *Risk Analysis 35*, 265 (2015)
[5] Q. Jiang,; T. Li,; Z.Liu,; H.Zhang,; K.Ren, *Journal of Cleaner Production 78*, 131 (2014)
[6] W. Yue, Y. Cai, L. Xu, Q. Tan and X. Yin, A. *Stochastic Environmental Research and Risk Assessment 31*, 961 (2017)
[7] J. F. Contadini, R. M. Moore and P. L. Mokhtarian, *International Journal of Life Cycle Assessment 7*, 73 (2002)
[8] E. Wang, Z. Shen, J. Neal, J. Shi, C. Berryman and A. Schwer, *International Journal of Life Cycle Assessment 17*, 764 (2012)
[9] K. Sasikumar and P. P. Mujumdar, *International Journal of Systems Science 31*, 575 (2000)
[10] E. Jahani, R. L. Muhanna, M. A. Shayanfar and M. A. Barkhordari, *Computer-Aided Civil and Infrastructure Engineering 29*, 208 (2014)