An Interval Fuzzy Multiobjective Watershed Management Model for the Lake Qionghai Watershed, China

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Abstract. Integrated watershed management is required to ensure the reasonable use of resources and reconcile interactions among natural and human systems. In the present study, an interval fuzzy multiobjective programming (IFMOP) method was used to solve an integrated watershed management problem. Based on system analysis, an IFMOP model suitable for a lake watershed system (IFMOPLWS) was developed and applied to the Lake Qionghai watershed in China. Scenario analysis and an interactive approach were used in the solution process. In this manner, various system components were incorporated into one framework for holistic consideration and optimization. Integrality and uncertainty, as well as the multiobjective and dynamic characteristics of the watershed system, were well addressed. Using two scenarios, two planning schemes were generated. Agriculture, tourism, macroeconomics, cropland use, water supply, forest coverage, soil erosion, and water pollution were fully interpreted and compared to identify a preferable planning alternative for local agencies. This study showed that the IFMOPLWS is a powerful tool for integrated watershed management planning and can provide a solid base for sustainable watershed management.

Key words: fuzzy, interval, Lake Qionghai watershed, multiobjective programming, scenario analysis, uncertainty, watershed management

1. Introduction

Watersheds are considered the most appropriate units for the management of water resources, water quality, and interactions among natural and human systems (Heathcote, 1998). Watersheds are complex systems (Newson, 1992) incorporating many components, including natural, economic, demographic, and political factors. These subsystems interconnect and interact, leading to four main characteristics of watershed systems: integrality, multiobjectiveness, dynamism, and uncertainty (Zou, 2000; Zhang et al., 2001).

Watershed management planning can be traced back to dam construction to mediate conflicts between upper and lower watersheds and better fulfill demands
for irrigation and power (Newson, 1992). In recent decades, watershed management planning has been strongly influenced by the wide recognition of and concern for sustainable development (Bulkley, 1995; Slocombe, 1998; Radif, 1999). In contrast to conventional watershed planning that aims primarily to exploit and utilize water and land resources, a more holistic approach is needed in modern watershed management (Viessman, 1996). Ecosystem conservation and interactions among socioeconomic–environmental entities must be integrated (Ballweber, 1995; Bulkley, 1995; Slocombe, 1998; Matondo, 2002). Thus, a proper method or framework is essential to integrate all system factors, effectively reflect the above characteristics of watershed systems, and reconcile conflicting activities within watersheds.

Multiobjective programming (MOP) is a reliable tool for working with complicated systems. It can incorporate various system components in a single framework and efficiently coordinate and optimize objectives. Many studies have examined MOP theories and applications (e.g., Cohen, 1978; Chang et al., 1995; Lee and Wen, 1996; Cho, 1999). Based on the deterministic MOP, stochastic MOP (SMOP) and fuzzy MOP (FMOP) methods were proposed to address uncertain system features, especially the uncertainty of system parameters (Zimmermann, 1978; Lai and Hwang, 1994; Chang et al., 1997). However, indispensable possibilistic or probabilistic information is usually unavailable for practical problems using SMOP and FMOP methods; for many system factors, only intervals can be identified. Therefore these methods have not been widely used and better ways for considering uncertainties are required (Huang et al., 1993; Wu et al., 1997; Zou et al., 2000).

Interval fuzzy multiobjective programming (IFMOP), a hybrid of inexact fuzzy linear programming (IFLP; Huang et al., 1993) and multiobjective optimization, is superior to the former MOP methods in its data requirements, solution algorithms, computational requirements, and results interpretation (Wu et al., 1997). IFMOP allows uncertainties presented as intervals to be directly communicated into planning processes through an interval linear programming algorithm (Huang, 1996; Wu et al., 1997). The interactive approach of this method helps account for the indispensable involvement of stakeholders. IFMOP has been successfully used in municipal solid waste management (Huang et al., 2002; Cheng et al., 2003), regional new-zone development planning (Zou et al., 2000), and optimal tourism management (Guo et al., 2001). IFMOP also incorporates some practices effective for watershed management. However, most practices focus on one or two aspects, such as water quality, land resources, or water resource planning (Huang, 1996; Wu et al., 1997; Zou et al., 1999). As the components considered in previous studies have been relatively simple, a more comprehensive IFMOP model is required for optimal management at a watershed scale. While such modeling has seen little use to date in watershed management, increased applications are expected as the method is developed further.

Integrated watershed planning and management are important to ensure the reasonable use of resources and harmonious socioeconomic–environmental