Chapter 3

Fuzzy Multi-Criteria Decision-Making Approach for Optimizing Sustainable Water Management

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ABSTRACT

This chapter explores the application of Fuzzy Multi-Criteria Decision-Making (FMCDM) in Optimizing Sustainable Water Management (SWM). FMCDM integrates fuzzy set theory and soft set theory to address the complexities and uncertainties involved in decision-making, especially in scenarios with multiple criteria and conflicting objectives. The chapter presents a methodological framework for applying

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FMCDM, which includes steps such as problem definition, fuzzification of data, fuzzy soft set (FSS) construction, weight assignment, aggregation, and ranking of alternatives. A case study demonstrates how this framework can be applied to assess water management strategies based on criteria like Water Quality Improvement, Cost Efficiency, Technological Feasibility, Environmental Sustainability, and Social Acceptability. The chapter highlights the benefits of FMCDM and provides structured decision support, while also addressing its limitations and suggesting future directions for enhancing its applicability in real-time, multi-stakeholder, and sustainability-focused decision-making contexts.

INTRODUCTION

The increasing demand for Sustainable Water Management (SWM) has led to the development of innovative methods for optimizing water resources, which is vital for ensuring the long-term availability of water. Water management is inherently complex, involving assessing various environmental, social, and economic factors. Thus, an integrated decision-making approach is required. Multi-Criteria Decision-Making (MCDM) methods have become essential in addressing these challenges by allowing stakeholders to evaluate and compare different water management strategies based on multiple criteria. These methods have been successfully applied to various water management contexts, including agricultural water management (Radmehr et al., 2022), irrigation water allocation (Elleuch et al., 2019), and wastewater treatment (Sharma et al., 2023).

MCDM approaches are beneficial when making uncertain decisions, as they allow for incorporating fuzzy logic to handle imprecise data (Zarghami & Szidarovszky, 2009). For instance, fuzzy techniques, such as the Fuzzy Analytic Hierarchy Process (AHP) and the Fuzzy Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), have been widely adopted in water resources management for evaluating water quality (Zyoud et al., 2016), optimizing water supply choices (Noori et al., 2020), and addressing the challenges of water loss management (Zyoud et al., 2016). Integrating expert judgment and stakeholder preferences makes decision-making more robust.

Furthermore, the emergence of hybrid MCDM approaches, which combine fuzzy logic with other techniques like AHP and TOPSIS, has proven effective in improving decision outcomes in complex scenarios, such as water resources planning (Afshar et al., 2011) and water quality assessment (Nourani & Najafi, 2022). These hybrid models enhance the accuracy of decision-making and provide a comprehensive framework for assessing the sustainability of water management practices, considering short-term and long-term impacts.

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