Chapter 1
Crisp and Fuzzy AHP in GIS-MCDA for Wildlife Habitat Suitability Analysis

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ABSTRACT

Geographic information system-based multi-criteria decision analysis (GIS-MCDA) is a process of decision making where geographical data and value judgments are integrated. Analytic hierarchy process (AHP) is a useful technique in MCDA for determining weights. This study focuses on the evaluation of GIS-MCDA using different uncertainty levels in AHP. Best suitable sites for tiger habitats are located and analyzed in Sariska Wildlife Reserve, India using crisp and fuzzy AHP in GIS-MCDA, and thereafter, an optimal habitat suitability model is proposed. The percentage deviation over the uncertainty levels ranges slightly over 5%. The relative difference between CAHP and FAHP is nearly 2.7%. Chi-square test reveals relationship between the degree of uncertainty and the difference between the maps. For real-world situations with increased variability, fuzzification is preferred and shows the best results. The worldwide declining status of the tigers is a serious threat to the overall biodiversity, and the methods adopted in this study thus target their conservation and management.

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INTRODUCTION

Geographic information system-based multi-criteria decision analysis (GIS-MCDA) is a process of decision making in which geographical data and value judgments are integrated to obtain information for decision makers. GIS-MCDA is used in a wide range of decision and management situations like environment planning and ecology management, urban and regional planning, hydrology and water resources, forestry, transportation, agriculture, natural hazard management, health-care resource allocation, etc. (Vahidnia et al. 2008, Sinha 2014). Analytic hierarchy process (AHP) (Saaty 1980, 1988) is an important and useful technique in decision making that has been widely used as a useful MCDA tool or a weight estimation technique in different cases (Vaidya and Kumar 2006, Sinha 2015, 2016). AHP is a method for ranking decision alternatives and selecting the best one when the decision maker has multiple criteria for analysis (Taylor 2004). The traditional AHP requires crisp judgments. However, AHP is often criticized for its inability to effectively handle the inherent uncertainty and imprecision associated with the mapping of the decision maker's perception to exact numbers (Deng 1999). AHP applications are used for suitability analysis in several cases (Banai-Kashani 1989, Eastman et al. 1992, 1993, Xiang and Whitley 1994). Although AHP method is a powerful tool in MCDA for spatial problems (Anselin et al. 1989, Kangas 1992, Correa-Berger 2006, Sinha et al. 2011, 2012, Sinha 2015, 2016), some researchers believe that Saaty's AHP method has some weaknesses (Yang and Chen 2004).

Decision maker obviously makes an uncertain estimation rather than a precise value in real-world cases. Humans are ineffective in making quantitative predictions, whereas they are comparatively efficient in qualitative assessment. In complex systems, the judgments of humans are symbolized by linguistic and vague patterns. Hence, better representation of this linguistics can be developed as quantitative data, which then can be refined by fuzzy set theory evaluation methods (Leung and Chao 2000, Kulak and Kahraman 2005, Ozdagoglu and Ozdagoglu 2007). Due to the complexity and uncertainty involved in real-world decision problems, fuzzy judgments provide better and more realistic decisions than crisp judgments. Since uncertainty and fuzziness are common characteristics in many decision-making problems, a fuzzy AHP (FAHP) method should be able to tolerate vagueness or ambiguity (Mikhailov and Tsvetinov 2004). In other words, the conventional AHP approach may not fully reflect a style of human thinking because the decision makers usually feel more confident to give interval judgments rather than expressing their judgments in the form of single numeric values, and so, FAHP can capture the appraisal of human for ambiguity when complex multi-attribute decision-making problems are considered (Erensal et al. 2006, Sinha 2014). Uncertainty lies within the parameters for the real-world problems like tiger habitat suitability, as with changing time due to its

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