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Procedia Engineering 23 (2011) 822 – 827

Procedia Engineering

www.elsevier.com/locate/procedia

A fuzzy ANP-based approach to evaluate region agricultural drought risk

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Abstract

With the global climate change, drought disasters occur frequently and caused huge economic loss. In this paper, a drought risk assessment model based on fuzzy Analytic Network Process (ANP) method is put forward. ANP is an extension of AHP method and can more reasonably reflect the interdependence between the same layers of evaluation index system. The index system of agricultural drought risk assessment is established. An application is demonstrated by Hunan Province agricultural drought in China from 2007 to 2009. The result shows that the method is effective for agricultural drought risk assessment.

Keywords: Drought disaster; risk assessment; Analytic Network Process (ANP); fuzzy evaluation

1. Introduction

Drought disaster is one of the most seriously natural disasters and become an important factor affecting the safety of water resources. It has an important impact on the development of world instability and becomes bottleneck of the sustainable development of national economy. China is one of the countries where drought disasters occur particularly frequently. According to statistics, the tremendous drought has occurred 1056 times and severe drought occurred averagely every two years within the 2155 years from 206 BC to 1949[1-2]. Among the five climatic disasters (drought, flood, typhoon, cold damage, heat wave) in the statistics from 1949 to 2005, the frequency of droughts is most frequently and about one-third of the total frequency of disasters[3]. Especially in the recent years, drought disasters continuously happen and cause serious impact to people's production and life. For example, 2009-2010, in the southwest of China, the five regions(Yunnan, Guangxi, Guizhou, Sichuan and Chongqing)

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1877-7058 © 2011 Published by Elsevier Ltd.
doi:10.1016/j.proeng.2011.11.2588

happened serious droughts. Therefore, it is significant to reduce drought risk by drought risk assessment, and adopt effective disaster prevention measures. In recent studies, many researchers applied ANP to decision-making problems [4-7]. In this paper, a drought risk assessment model based on fuzzy analytic network process (ANP) method was put forward and applied to assessment Hunan Province agricultural drought in China.

2. Fuzzy ANP method

Analytic network process (ANP) was firstly brought out by Satty in 1996[8]. ANP not only can solve the AHP problem, but also can deal with interdependent relationships within a multi-criteria decision-making model. With factors influenced each other, and dependent on each other in the network layer, important degree can use direct comparison or indirect comparison. The mainly step are as follows. Firstly, constructing pairwise matrices of the components with fuzzy judgments and determining the local priorities, consistency index from each matrix using the fuzzy prioritization method. Secondly, checking the consistency index and aggregate local priorities into group priorities using nonlinear programming approach as explained. Thirdly, filling the super matrix with the elicited group priorities to form unweighted super matrix, and obtain weighted super matrix by multiplying the unweighted super matrix by the corresponding cluster priorities, and then adjusting the resulting super matrix to column stochastic. Fourthly, limit the weighted super matrix by raising it to sufficiently large power so that it converges into a stable super matrix (all columns being identical) and normalize the scores of alternatives from the limit weighted super matrix into final priorities. Through the above steps, we can obtain relative to the general objective factors, and ultimately the list weight of each factor. As using ANP method to solve practical problems is complex, so we must use special calculation software. The Super Decisions software will be used to evaluate the risk in this paper. The mainly process of fuzzy ANP method as follows.

(1) Dividing different grades and choosing a set. The set is evaluation result sets that are made by experts, namely: $\mathrm{v}=\{v_1,v_2,...,v_i\}\ (i=1,2,3\ldots)$, $v_i\ (i=1,2,3\ldots)$ are all sorts of evaluation results.

(2) Screening risk assessment factors for constituting a factor sets *f*, then, use the ANP method to determine weight.

(3) Make single factor evaluation and establish fuzzy judgment matrix. Take Delphi method to establish fuzzy judgment matrix R. To evaluate the factors by Delphi method or random survey so as to access to a degree of comments r_{ij} that belong to $i=1,2,\cdots,n$, then we can get fuzzy judgment matrix:

$$R=\begin{pmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ r_{m1} & r_{m2} & \cdots & r_{nm} \end{pmatrix}$$

(4)Computing membership vector B

The membership vector B can be computed by $B=W*R$.

3. Case study

The drought disaster risk of Hunan province in China is taken as an example in this paper. Hunan is a major agricultural province with a very special natural climatic and topographic condition. In recent years, Hunan province has the high frequency of drought and severe agricultural drought, and agricultural drought occurs almost every year[9]. According to Statistical Yearbook of Hunan Province, Water Resource Bulletin and relevant literature, there are mainly four factors affecting agricultural drought risk: