Journal of Geoscience and Environment Protection, 2024, 12, 347-354
https://www.scirp.org/journal/gep
ISSN Online: 2327-4344
ISSN Print: 2327-4336

Comprehensive Benefit Evaluation Method of Mountain Flood Disaster Prevention and Control in Jiangxi Province Based on Matter-Element Extension Model

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How to cite this paper: Liu, P. X., Shao, Y. B., Ye, J. W., Shi, P. P., Yuan, D. B., & Xu, Z. W. (2024). Comprehensive Benefit Evaluation Method of Mountain Flood Disaster Prevention and Control in Jiangxi Province Based on Matter-Element Extension Model. *Journal of Geoscience and Environment Protection, 12,* 347-354.
https://doi.org/10.4236/gep.2024.1210019

Received: September 12, 2024
Accepted: October 28, 2024
Published: October 31, 2024

Abstract

Taking the mountain flood disaster prevention and control project in Jiangxi province as the research object, the evaluation period is 2010-2015, and 29 evaluation indexes are selected from 7 aspects. In this paper, game theory is introduced to optimize the subjective and objective weights of the index, and the comprehensive weights are obtained by normalization. The results show that the eigenvalues of the grade variables of benefit evaluation decreased from 3.43 to 2.03, indicating that the project of mountain flood disaster prevention and control in Jiangxi province brings into play the benefits year by year, and the eigenvalues tend to decrease steadily after 2012, it is consistent with the changes of various engineering measures and non-engineering measures in the project.

Keywords

Index System, Numerical Model, Comprehensive Evaluation

1. Introduction

The process of mountain torrents is complicated by topography and the underlying surface, which makes mountain torrents have the characteristics of high difficulty in prediction and Prevention and great harm (Sun et al., 2022). The province

has one of the worst flash floods in the country, accounting for nearly 70 percent of all deaths from flash floods, according to the 2000-2023. In 2004, Jiangxi Province compiled and completed the "Report on Mountain Flood Disaster Prevention and control plan of Jiangxi Province"(Bolun et al., 2024); In 2007-2009, Jiangxi Province carried out the first, second and third phases of construction of flash flood disaster early warning system in 56 counties (cities and districts), ninety-four counties (cities and districts) in Jiangxi province were included in the National Mountain Flood disaster non-engineering measures project at the county level (Wang et al., 2021); In 2012, the National Mountain Flood Disaster Prevention and control project was launched, and Jiangxi province subsequently carried out related work comprehensively. With the implementation of the project of prevention and control of mountain torrents in Jiangxi province, the harm of mountain torrents has been reduced to a certain extent. How to objectively evaluate the effect of the implementation of the project has become a difficult problem after the implementation of the mountain flood disaster prevention and Control Project, at present, the research on mountain torrents mainly focuses on mountain torrents disaster risk assessment and regionalization, mountain torrent disaster prevention and control measures, mountain torrent disaster early warning and forecast, etc., there are few studies on the theory and method of Project Implementation Benefit Evaluation (Guo et al., 2021). Based on the related work, this paper aims to take Jiangxi province, where mountain torrents frequently occur, as the study area, through the technical means of data collection, field investigation, scientific statistics and data processing, etc., a scientific evaluation system of Mountain Flood Disaster Prevention and Control Project Benefit is established by selecting the Comprehensive Evaluation Index guided by the project implementation effect, and the evaluation of mountain flood disaster prevention and control benefit in Jiangxi province based on matter-element extension method is discussed, the problems existing in the prevention and control of mountain torrents should be found and corrected in time to provide the scientific basis for the formulation of disaster prevention and reduction measures.

2. Materials and Methods

2.1. Comprehensive Benefit Evaluation Index System

According to the construction situation and characteristics of the mountain flood disaster prevention and control project, taking the National Water Conservancy construction project evaluation criterion as the standard (Wang et al., 2024), considering engineering construction, project management, comprehensive benefit, science and Technology and sustainability, 29 evaluation indexes were selected according to local conditions to construct the evaluation index system of Mountain Flood Disaster Control project in Jiangxi province, the index factors and attributes are shown in **Table 1**.

Table 1. Comprehensive benefit evaluation index of mountain flood disaster prevention and control projects.

Level 1	Level 2	Level 3
Comprehensive Benefit Evaluation of Mountain Flood Control Project	Construction Management A	Rules and regulations A1
		Pre-work A2
		Implementation of the four systems A3
		Acceptance A4
	Completion status B	To investigate and evaluate the completion of the project B1
		Completion of non-engineering measures B2
		Completion of engineering measures B3
	Construction objectives C	Survey and evaluation of coverage C1
		Automatic monitoring system C2
		Monitoring and early warning platform C3
		Early Warning release system C4
		Group Test Group defense system C5
	Economic benefits and ecological and environmental benefits D	GDP D1
		Reduce the destruction of the ecological environment D2
		Protect the land resources of the hills D3
		Improve the living environment D4
	Social benefits E	Reduce casualties E1
		Improve flood control and drought resistance E2
		A comprehensive system for the prevention and control of mountain torrents shall be established E3
		Improving public services E4
		Enhance the ability of disaster prevention and risk avoidance E5
	Science and technology F	Theoretical Innovation F1
		Technological Innovation F2
		Patent for publication of articles F3
		Personnel training F4
	Sustainability assessment G	Implementation of Operation Management and maintenance system G1
		Operating maintenance funds G2
		Operations Manager G3
		Level of support G4

2.2. The Initial Weight of the Index Is Calculated

1) Analytic hierarchy process. The analytic hierarchy process (AHP) is a systematic analysis method, whose principle is to decompose the complex problem into an orderly and progressive hierarchical structure, which makes people's thinking process systematic and mathematical, and determines the relative importance of each factor through comparison, then calculates the weight of each factor.

2) Entropy method. The concept of entropy is derived from thermodynamics, and it is a measure of system order. If the information entropy of the index is smaller, the variation of the index is larger, and the amount of information provided is larger, the corresponding weight is larger.

3) Combination weight calculation based on game theory. Based on the minimum deviation criterion between the combination weight and the basic weight, the subjective weighting method (analytic hierarchy process) and the objective weighting method (entropy method) are optimized by game theory to obtain the comprehensive weight.

2.3. Construction of Matter-Element Extension Mode

2.3.1. Model Theory

The principle of matter-element extension model is to take evaluation index system and measured value as matter-element, determine classical domain and nodal domain based on different grading standards and grades, and establish extension matrix by using correlation function, the closer the degree of closeness is, the closer the degree of closeness is, and the smaller the eigenvalue is, the higher the evaluation grade.

2.3.2. Reenforce

Rating variables eigenvalues j^* rating:

$$j^* = \frac{\sum_{i=1}^{m} j\bar{N}_j(P_0)}{\sum_{i=1}^{m} \bar{N}_j(P_0)}$$

The classical domain is determined according to the characteristic of matter-element to be evaluated and the range of its value. The grade is divided into M grades, Grade $N_j = (1, \cdots, m)$ is represented by j, i is the Evaluation Index, N is the eigenvector, P is the initial matrix.

3. Benefit Evaluation of Mountain Flood Control Project in Jiangxi Province

3.1. Overview of the Study Area

According to "Jiangxi Province Statistical Yearbook" and "Jiangxi Province from 2010 to 2015 Flash Flood Disaster Prevention and Control Project Construction Data", Select **Table 1** of the Flash Flood Disaster Prevention and Control Project in Jiangxi Province Comprehensive Benefit Evaluation Indicators, in this paper, the analytic hierarchy process (AHP-RRB- and entropy weight method are introduced to determine the subjective weight and objective weight of evaluation indexes respectively, then it is normalized to get the comprehensive weight. The comparison of subjective weight, objective weight and comprehensive weight of each evaluation index is detailed in **Figure 1**.

3.2. The Index Weight Is Determined

According to "Jiangxi Province Statistical Yearbook" and "Jiangxi Province from

2010 to 2015 Flash Flood Disaster Prevention and Control Project Construction Data", Select **Table 1** of the Flash Flood Disaster Prevention and Control Project in Jiangxi Province Comprehensive Benefit Evaluation Indicators, in this paper, the analytic hierarchy process (AHP-RRB- and entropy weight method are introduced to determine the subjective weight and objective weight of evaluation indexes respectively, then it is normalized to get the comprehensive weight. The comparison of subjective weight, objective weight and comprehensive weight of each evaluation index is detailed in **Figure 1**.

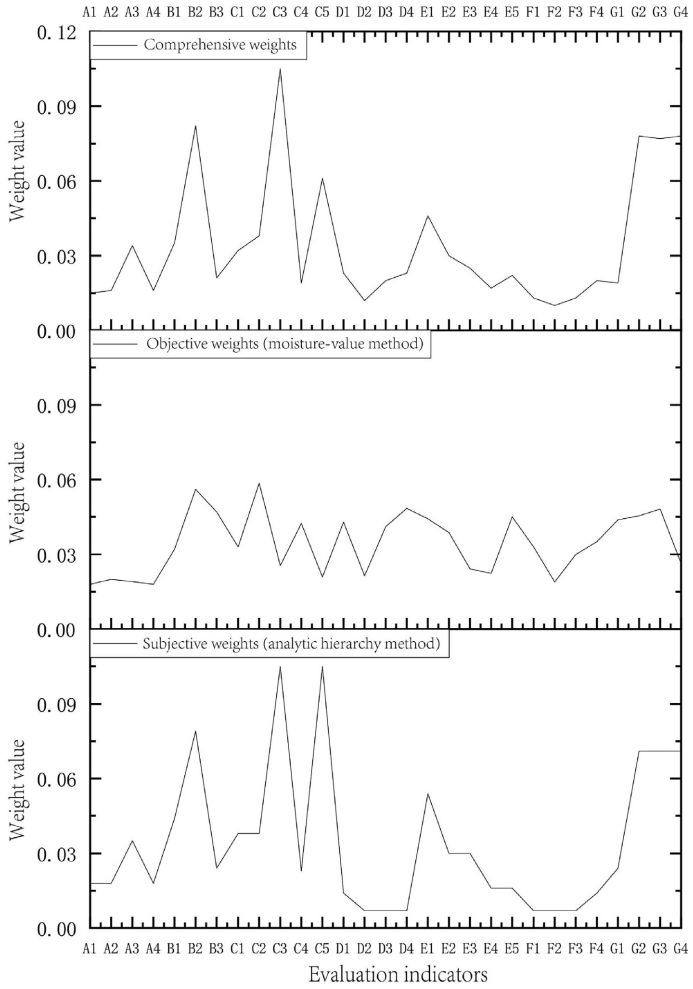

Figure 1. Weight of comprehensive benefit evaluation index of mountain flood disaster prevention and control projects.

3.3. Benefit Evaluation of Mountain Flood Disaster Project Based on Matter-Element Extension Model

According to the 2010-2015 calendar year of the indicators, Equations (3)-(8) were used to calculate the year of the variable eigenvalues; the results are shown in **Figure 2**. According to the change of evaluation indexes, the characteristic values of each index basically show a trend of increasing year by year, which indicates that every qualitative or quantitative statistical index is getting better.

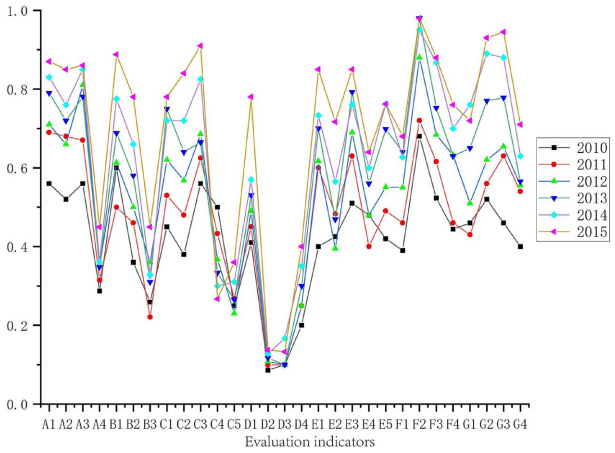

Figure 2. Characteristic values of benefit evaluation indicators of mountain flood disaster prevention and control projects in Jiangxi Province from 2010 to 2015.

Calculating the average of the eigenvalues of each evaluation index from 2010 to 2015 can compare the relationship between the eigenvalues of each index, as shown in **Figure 3**. The annual average of the eigenvalues of the "Technological innovation" index is the highest, reaching 0.865, and the annual average eigenvalue of the index of "Ecological environment destruction reduction and relief in mountainous areas" is the smallest, only 0.113. From the average of the eigenvalues of the two-level indexes, "Science and technology" > "Sustainability assessment" > "Construction management" > "Social benefits" > "Construction objectives" > The average eigenvalues of the first six secondary indicators are all above 0.5, and only the average annual eigenvalues of "Economic and ecological environmental benefits" are 0.265, this indicates that the two-level index "Economic and eco-environmental benefits" and its three-level index measure eigenvalue is small, and the inter-annual change is small, which also coincides with the actual situation.

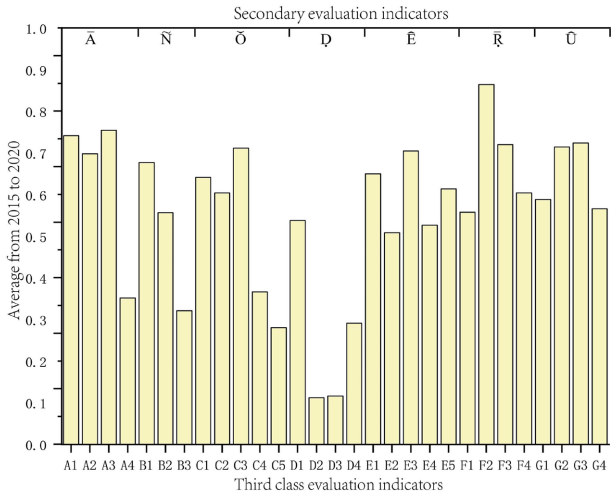

Figure 3. Annual average value of benefit evaluation index of mountain flood disaster prevention and control projects in Jiangxi Province from 2010 to 2015.

Through model analysis and calculation, the characteristic values of the grade variables of the comprehensive benefit evaluation of the mountain flood disaster prevention and control projects in Jiangxi province from 2010 to 2015 are 3.43, 3.32, 2.47, 2.35, 2.17 and 2.03 respectively, showing a decreasing trend year by year, it shows that the project of Mountain Flood Disaster Prevention and control is playing an important role year by year, and the comprehensive benefit of the project shows a better and better trend. However, the eigenvalue decreased from 3.32 in 2011 to 2.47 in 2012, with a decrease of 0.85, which was the period with the largest variation in the adjacent years during the evaluation period. After 2012, the eigenvalue tended to be stable, the evaluation results are consistent with the annual changes of each evaluation index: the monitoring and early warning platform, various engineering measures, group monitoring and group prevention system and other non-engineering measures in the prevention and control project of mountain torrents in Jiangxi province generally need two to three years to be gradually completed, after the project is completed, the comprehensive benefits of mountain flood disaster prevention and control can be improved significantly.

4. Conclusions

The evaluation results show that the characteristic values of the evaluation variables of mountain flood disaster control projects in Jiangxi province are decreasing year by year from 2010 to 2015, indicating that the mountain flood disaster control projects in Jiangxi province are bringing into play the benefits year by year, since 2012, the eigenvalues have stabilized, mainly because it takes two to three years for engineering and non-engineering measures in flash flood prevention and control projects to be gradually completed, after construction, the benefits of mountain flood control can be improved significantly. The evaluation results are in agreement with the actual annual changes, indicating that the selected indexes and models can be used to evaluate the benefits of mountain flood control projects, it can also provide a reference for other subjective and objective indicators of mixed system benefit evaluation.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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