ISSN 2616-5872 Vol.6, Issue 6: 39-44, DOI: 10.25236/AJEE.2024.060606

Evaluation of the Current Status of Grassland Degradation in Ganzi Prefecture Based on FAHP-FCE

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Abstract: *This paper considers the current situation of grassland degradation in Ganzi Prefecture. The fuzzy analytic hierarchy process (FAHP) is applied to establish an index evaluation system. The current situation of grassland degradation in Ganzi Prefecture is divided into three dimensions, and 11 index factors affecting grassland degradation in Ganzi Prefecture are determined. The geometric mean method is used to determine the weights of each evaluation index. The results show that human-caused destruction and abnormal climate are the main factors of grassland degradation in Ganzi Prefecture, and their combined contribution to the grassland degradation rate reaches 72.32%. Over-grazing, decreased precipitation, rodent and pest damage, and over-reclamation are the four main reasons for grassland degradation in Ganzi Prefecture, and the total contribution rate of these four factors is 41.14%. On the other hand, the fuzzy comprehensive evaluation (FCE) is used to conduct a comprehensive evaluation of the current situation of grassland degradation in Ganzi Prefecture. The evaluation results show that the comprehensive evaluation result of the current situation of grassland degradation in Ganzi Prefecture is "slightly degraded".*

Keywords: *Ganzi Prefecture; grassland degradation; fuzzy analytic hierarchy process; fuzzy comprehensive evaluation*

1. Introduction

Grassland degradation refers to the phenomenon that climate or human-induced disturbances exceed the self-regulation threshold of the grassland ecosystem, making it difficult to recover and resulting in reverse succession changes [1]. In recent years, due to issues such as global warming and population growth, about 90% of grasslands have degraded to some extent [2]. Ganzi Prefecture is located at the west of Sichuan Province and belongs to the special ecological area of the Qinghai-Tibet Plateau. 80% of the water systems at the sources of the Yangtze River and the Yellow River lie in Ganzi Prefecture, and 80% of the water-conservation areas at the source of the Yangtze River are alpine meadow grasslands in Ganzi Prefecture. The grasslands in Ganzi Prefecture are the main part of the ecological barrier of the Jinsha River, Yalong River, and Dadu River, which are the main tributaries of the upper reaches of the Yangtze River. They have ecological functions such as soil and water conservation, water-source conservation, wind-break and sand-fixation, and maintenance of biodiversity [3]. Due to the impacts of climate change and human activities, the ecological environment in this region has deteriorated, and the water-source conservation function of grasslands has declined, which has become an important issue for ecological security protection in Sichuan Province and even in the Yangtze River and Yellow River basins [4].

Song [5] and Zhou [6] analyzed the harms brought by the degradation of alpine grasslands in Ganzi Prefecture and discussed the causes of such degradation as well as the establishment of a long-term protection mechanism. Liang discussed the causes of the degradation of alpine meadows in Ganzi Prefecture from three aspects: climatic factors, human factors, and habitat factors, and put forward the restoration strategies for alpine meadows [7]. However, references [5-7] only analyzed the factors contributing to the degradation of grasslands in Ganzi Prefecture qualitatively and failed to indicate the current situation of grassland degradation in Ganzi Prefecture and the contribution rates of various factors to the grasslands.

On the other hand, the analytic hierarchy process has been successfully applied to study the

ISSN 2616-5872 Vol.6, Issue 6: 39-44, DOI: 10.25236/AJEE.2024.060606

contribution degrees of grassland degradation factors [8-10]. For instance, Wang [10] studied the contribution magnitudes of the influencing factors of the degradation of alpine grasslands in Northern Tibet based on the analytic hierarchy process. Since there is inherent fuzziness in the evaluation of grassland degradation, this paper will determine the contribution magnitudes of various factors of grassland degradation in Ganzi Prefecture by applying FAHP and evaluate the situation of grassland degradation in Ganzi Prefecture using FCE.

2. Methodology

2.1. Construction of the Evaluation Index System

The integrity and accuracy of the index system determine the accuracy of the evaluation results. A scientific evaluation index system is the prerequisite for a scientific and objective evaluation of the current situation and factors of grassland degradation. According to references [4-7], combined with the actual situation of grassland degradation in Ganzi Prefecture, an index system suitable for the evaluation of grassland degradation in Ganzi Prefecture was selected to judge the grassland degradation in Ganzi Prefecture from three dimensions: climate, human factors, and habitat. The evaluation of grassland degradation in Ganzi Prefecture serves as the target layer; three first-level evaluation indicators, namely abnormal climate, human destruction, and poor habitat, form the criterion layer. Among them, the abnormal climate includes three second-level evaluation indicators, human destruction includes five second-level evaluation indicators, and poor habitat includes three second-level evaluation indicators. There are a total of 11 second-level evaluation indicators, which constitute the factor layer (see Table 2).

2.2. Contribution Rate of Factors for Grassland Degradation

This study applies the fuzzy analytic hierarchy process to determine the contribution degree of factors for grassland degradation. Generally, there are the following three steps to solve the contribution degree of factors for grassland degradation [9] as follows.

Step 1: Construct a fuzzy complementary judgment matrix. Conduct pairwise comparisons and scaling of different factors at the same level through the method of expert scoring. According to the results of pairwise comparisons of various factors, construct a fuzzy complementary judgment matrix $H = (h_{ij})_{n\times n}$. The comparison scale of the judgment matrix is shown in Table 1. The 0.1-0.9 quantitative scale is adopted to illustrate the fuzzy relationship of the importance degree among them.

Step 2: Transform the fuzzy complementary matrix $H = (h_{ij})_{n\times n}$ into the fuzzy consistent matrix $R = (r_{ij})_{n\times n}$. Define

$$r_i = \sum_{k=1}^{n} h_{ik}, i = 1,2,\cdots,n. \tag{1}$$

Let

$$r_{ij} = \frac{r_i - r_j}{2n} + 0.5. \tag{2}$$

Therefore, according to (1-2), the fuzzy judgment matrix $H = (h_{ij})_{n\times n}$ is transformed into the fuzzy consistent matrix $R = (r_{ij})_{n\times n}$.

Table 1: Meaning of the fuzzy complementary judgment matrix scale

Degree of importance	h_{ij}	h_{ji}
a_i is equally important as a_j	0.5	0.5
a_i is slightly more important than a_j	0.6	0.4
a_i is significantly more important than a_j	0.7	0.3
a_i is much more important than a_j	0.8	0.2
a_i is extremely more important than a_j	0.9	0.1

Step 3: Calculate the contribution degrees of grassland degradation factors. The geometric mean value method is used to obtain the fuzzy weight vector $\omega = (\omega_1, \omega_2, \cdots, \omega_n)$, that is, the contribution degrees of grassland degradation factors. Let

$$S_i = \left(\prod_{j=1}^{n} r_{ij}\right)^{\frac{1}{n}}, i = 1,2,\cdots,n, \tag{3}$$

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then

$$\omega_i = \frac{s_i}{\sum_{i=1}^{n} s_i}, \tag{4}$$

is the contribution degree of factor i degradation.

2.3. Evaluation of the Current Situation of Grassland Degradation.

This study uses the fuzzy comprehensive evaluation method to conduct a comprehensive assessment of the current state of grasslands. Fuzzy comprehensive evaluation is based on fuzzy mathematics and applies the principle of fuzzy relation composition to quantify some factors with unclear boundaries and that are not easily quantified. Using the principles of fuzzy linear transformation and the maximum membership principle, and considering various factors related to the evaluated object, a comprehensive assessment is made. The specific steps are as follows.

Step 1: Establish the index factor set. The index factor set is

$$U = \{u_1, u_2, \cdots, u_m\}, \tag{5}$$

where $u_i,\ i = 1,2,\cdots,m$ are the index factors of the evaluation index system, with a certain degree of fuzziness, and m is the number of index factors of the evaluation index system. This study will use the 11 secondary indicators in Table 2 as the factor set.

Table 2: Summary of evaluation index weights of Grassland Degradation in Ganzi Prefecture

Target level	Guideline level	Weight	Indicator level	Weight	C-level weight	Total sorting
Evaluation of grassland degradation in Ganzi Prefecture A	Abnormal climate B_1	0.3447	Decrease in precipitation C_{11}	0.3557	0.1102	2
			Rise in temperature C_{12}	0.3445	0.0867	7
			Decrease in sunshine duration C_{13}	0.2998	0.0825	10
	Human-caused destruction B_2	0.3785	Over-grazing C_{21}	0.2534	0.1128	1
			Excessive reclamation C_{22}	0.2124	0.0934	4
			Medicinal material excavation C_{23}	0.1877	0.0850	8
			Road construction C_{24}	0.1918	0.0876	6
			Resource development C_{25}	0.1546	0.0707	11
	Poor habitat B_3	0.2769	Soil erosion C_{31}	0.3333	0.0842	9
			Rodent and pest damage C_{32}	0.3669	0.0985	3
			Harm of poisonous weeds C_{33}	0.2998	0.0884	5

Step 2: Set the evaluation grade set. The comment set is recorded as

$$V = \{v_1, v_2, \cdots, v_k\}, \tag{6}$$

where $v_i,\ i = 1,2,\cdots,k$ are the comment indicators, and k is the number of comment indicators. According to references [4 - 5], this study divides the comment indicators into 4 grades, recorded as

$$V = \{\text{Non} - \text{degraded}, \text{Slightly degraded}, \text{Moderately degraded}, \text{Severely degraded}\}. \tag{7}$$

Step 3: Establish a fuzzy evaluation matrix. Evaluate each index factor against the comment set by distributing questionnaires, and perform normalization processing to obtain the final fuzzy evaluation matrix, denoted as

$$T = \left(t_{ij}\right)_{m\times k}. \tag{8}$$

Step 4: Construct the fuzzy comprehensive evaluation result set. Perform fuzzy compound operations on the fuzzy relation evaluation matrix T and the corresponding weight ω (the contribution degree of each index in the evaluation index system) to construct the corresponding fuzzy comprehensive evaluation result set as follows:

$$Y = \omega * T = (y_1, y_2, \cdots, y_m), \tag{9}$$

where $*$ is the fuzzy operator, and in this study, the weighted average - type fuzzy operator is adopted.

Step 5: Determine the fuzzy comprehensive evaluation. According to the principle of maximum membership degree, determine the grade with the maximum membership degree in Y as the final

ISSN 2616-5872 Vol.6, Issue 6: 39-44, DOI: 10.25236/AJEE.2024.060606

evaluation of the current situation of grassland degradation.

3. Empirical Analysis of Grassland Degradation Evaluation in Ganzi Prefecture

3.1. Weights of Each Evaluation Indicator.

Based on the fuzzy complementary judgment matrix obtained through expert scoring, the fuzzy complementary judgment matrix can be transformed into a fuzzy consistent matrix using (1-2). The weight values of each factor on each layer can be calculated according to (3-4), and finally summarized into the summary table of the weights of evaluation indicators for each factor of grassland degradation in Ganzi Prefecture, as shown in Table 2.

3.2. Fuzzy comprehensive evaluation

To construct the fuzzy evaluation matrix, a questionnaire was developed based on the indicator layer in Table 2 and (5-6). The questionnaire invited 5 experts and 10 herdsmen to evaluate the 11 indicators of the indicator layer, and 15 valid questionnaires were collected. After calculating the proportion of the number of people corresponding to each evaluation grade, the evaluation matrix of each indicator factor can be established (see Table 3).

Table 3: Evaluation Matrix of Factors for Grassland Degradation in Ganzi Prefecture

Indicator name	Judging values			
	Severely degraded	Moderately degraded	Slightly degraded	Non-degraded
C11	0.00	0.20	0.80	0.00
C12	0.00	0.33	0.67	0.00
C13	0.00	0.07	0.93	0.00
C21	0.00	0.53	0.33	0.13
C22	0.00	0.13	0.80	0.07
C23	0.00	0.00	0.33	0.67
C24	0.00	0.00	0.80	0.20
C25	0.00	0.00	0.93	0.07
C31	0.00	0.00	1.00	0.00
C32	0.07	0.80	0.13	0.00
C33	0.00	0.40	0.40	0.20

According to Table 2, the weight vectors of each factor layer can be obtained as follows:

$$\begin{cases} \omega_A = (0.3447, 0.3785, 0.2769), \\ \omega_{B_1} = (0.3557, 0.3445, 0.2998), \\ \omega_{B_2} = (0.2534, 0.2124, 0.1877, 0.1918, 0.1546), \\ \omega_{B_3} = (0.3333, 0.3669, 0.2998). \end{cases} \tag{10}$$

According to Table 3, the fuzzy comprehensive evaluation matrices $T_{B_i}(i = 1,2,3)$ of each factor in the criterion layer of this study can be obtained as follows:

$$T_{B_1} = \begin{pmatrix} 0.00 & 0.20 & 0.80 & 0.00 \\ 0.00 & 0.33 & 0.67 & 0.00 \\ 0.00 & 0.07 & 0.93 & 0.00 \end{pmatrix}, \tag{11}$$

$$T_{B_2} = \begin{pmatrix} 0.00 & 0.53 & 0.33 & 0.13 \\ 0.00 & 0.13 & 0.80 & 0.07 \\ 0.00 & 0.00 & 0.33 & 0.67 \\ 0.00 & 0.00 & 0.80 & 0.20 \\ 0.00 & 0.00 & 0.93 & 0.07 \end{pmatrix}, \tag{12}$$

$$T_{B_3} = \begin{pmatrix} 0.00 & 0.00 & 0.10 & 0.00 \\ 0.07 & 0.80 & 0.13 & 0.00 \\ 0.00 & 0.40 & 0.40 & 0.20 \end{pmatrix}. \tag{13}$$

According to (9-13), the sets $Y_i(i = 1,2,3)$ of membership degrees of each factor in the criterion layer for the fuzzy comprehensive evaluation comment set can be obtained. By superimposing the sets

ISSN 2616-5872 Vol.6, Issue 6: 39-44, DOI: 10.25236/AJEE.2024.060606

of membership degrees of each factor into a matrix, the fuzzy comprehensive evaluation matrix T of the target layer can be obtained as follows:

$$T = \begin{pmatrix} Y_1 \\ Y_2 \\ Y_3 \end{pmatrix} = \begin{pmatrix} 0 & 0.2058 & 0.7942 & 0 \\ 0 & 0.1619 & 0.6127 & 0.2228 \\ 0.0257 & 0.4134 & 0.2009 & 0.0600 \end{pmatrix}. \quad (14)$$

According to (9) and (14) again, the fuzzy comprehensive evaluation result Y of the final target layer can be further obtained, that is

$$Y = (0.071, 0.2467, 0.5613, 0.1009). \quad (15)$$

4. Conclusion

This study is based on FAHP - FCE, constructing a grassland degradation evaluation system model for Ganzi Prefecture with three levels, three dimensions, and eleven evaluation indicators. Through the combined method of expert scoring and questionnaire surveys, the importance of each evaluation indicator is determined, and an analysis and evaluation are carried out, resulting in the following conclusions.

From Table 2, it can be seen that $B_2 > B_1 > B_3$, indicating that human-caused destruction and abnormal climate are the main factors of grassland degradation in Ganzi Prefecture, and their combined contribution to the grassland degradation rate reaches 72.32%. However, it is worth noting that poor habitat conditions cannot be ignored, with a contribution rate to grassland degradation of 27.69%. On the other hand, from the overall ranking in Table 2, over-grazing, decreased precipitation, rodent and pest damage, and over - reclamation are the four main reasons for grassland degradation in Ganzi Prefecture, with the contribution rate of these three factors being 41.14%. Therefore, grassland degradation management should mainly consider these four factors.

In (15), according to the principle of maximum membership degree, the membership degree of the comment "slightly degraded" is 0.5613, which is the maximum value of the comment set. Therefore, the comprehensive evaluation result of the current situation of grassland degradation in Ganzi Prefecture can be evaluated as mainly being in a "slightly degraded" state.

Acknowledgements

This work was supported by Ganzi Prefecture Key Research Base of Philosophy and Social Sciences: Northwest Sichuan Ecological Economic Development Research Center of Sichuan Minzu College (Project Name: "Research on the Driving Factors of Grassland Degradation in the Northwest Sichuan Plateau and Its Economic Impact", Project Number: CXBSTJJ202425).

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